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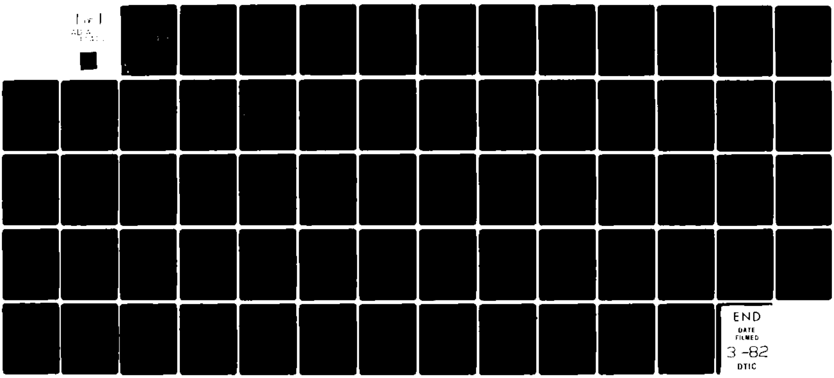

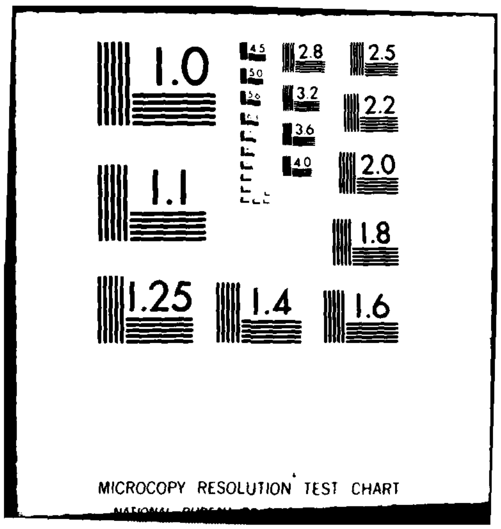
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Report No. EPL-81-2/USACERL-81-1

# The Production of Specified Electrocortical Activity as a Measurable Task



TECHNICAL REPORT

Prepared for: The U. S. Army Construction Engineering Research Laboratory and the Air Force Office of Scientific Research

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| REPORT DOCUMENTATION PAGE | | READ INSTRUCTIONS BEFORE COMPLETING FORM |
|---|---|---|
| 1. REPORT NUMBER EPL-81-2/USACERL-81-1 | 2. GOVT ACCESSION NO. AD-A112 | 3. RECIPIENT'S CATALOG NUMBER |
| 4. TITLE (and Subtitle) THE PRODUCTION OF SPECIFIED ELECTROCORTICAL ACTIVITY AS A MEASURABLE TASK | | 5. TYPE OF REPORT & PERIOD COVERED TECHNICAL |
| | | 6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s) Dennis B. Beringer, Michael G. H. Coles | | 8. CONTRACT OR GRANT NUMBER(s) DACA-88-80-C-0003 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS The University of Illinois, Dept. of Indus. Engr Engineering Psychology Laboratory Champaign, Illinois 61820 | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 61102 AT23 |
| 11. CONTROLLING OFFICE NAME AND ADDRESS U.S. ARMY CONSTRUCTION ENGINEERING RESEARCH LAB Interstate Research Park, Champaign, IL 61820 Air Force Office of Scientific Research (NL) Bolling Air Force Base, DC 20332 | | 12. REPORT DATE February 1981 |
| | | 13. NUMBER OF PAGES 60 |
| 14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Same | | 15. SECURITY CLASS. (of this report) UNCLASSIFIED |
| | | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Electrocortical Activity
Productivity
Alpha Production
Cognitive Models
Feedback Utilization
Biofeedback
Micropressor Systems

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Global electrocortical activity (alpha) was examined as a possible index of subtle environmental effects upon productivity in cognitive tasks. A new model of biofeedback was proposed to account for the various effects described in the literature. Although consistent with previous findings, the model received no additional confirmation from the current study. It was concluded that the measure was overly sensitive and unstable. Other multivariate measurement schemes were suggested.

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# FOREWORD

This study was jointly funded by the Office, Chief of Engineers under project 4A161102AT23, and the Air Force Office of Scientific Research under Program Element 61102F, Project/Task 2313/A3. The study was performed under contract by the Engineering Psychology Laboratory of the Department of Industrial Engineering, University of Illinois at Urbana-Champaign. The contract was monitored by the Facility Systems Division, U. S. Army Construction Engineering Research Laboratory, Champaign, IL.

# TABLE OF CONTENTS

## LIST OF TABLES

# LIST OF FIGURES

# INTRODUCTION

During the last decade, considerable attention has been paid to the possible application of EEG Biofeedback Training in a number of different situations. However, research to date has indicated that biofeedback has few, if any, beneficial effects. There have been two major areas in which the search for possible application has been pursued. In the clinical area, it was believed that the production of alpha activity through biofeedback techniques would produce a state antithetical to many clinical disorders such as anxiety and depression. However, as Sterman (1977) indicates, the promise of biofeedback in this area has not been realized. A second area of disappointment has been that of performance enhancement. Lawrence and Johnson (1977) reviewed the research in this area and concluded that "enhanced alpha activity does not prevent sleep loss effects or substitute for sleep . . . is not related to memory or choice reaction time performance . . . does not provide a recuperative break period . . . and is incompatible with cognitive tasks requiring any degree of effort" (pg. 166). Thus, the promise of biofeedback as a panacea in clinical and human performance applications has not been realized.

The present studies take a different approach to the potential application of biofeedback. Instead of seeking beneficial effects from feedback procedures, the approach seeks to evaluate whether performance on a biofeedback task can be used as a measure of the effects of work environment. Briefly stated, the research is predicated on the hypothesis that the biofeedback task involves the allocation of resources or capacity. External events (environmental stimuli) or internal events (cognitive processes) can interfere with the biofeedback task since they draw on resources involved in the task. Thus, performance on

the biofeedback task can be used as an index of the degree to which environmental events and cognitive events call upon the same processes that are involved in the task. Before expanding on the theoretical basis for these predictions, we need to consider various models of biofeedback.

## Models of Biofeedback

Mulholland's systems approach. The feedback system described by Mulholland (1977) is based on a generalized feedback control system (Figure 1). Empirically, it has been tested using biofeedback of EEG with a feedback stimulus being one which itself influences the EEG. In most studies, a visual feedback stimulus is used and occipital EEG recorded. The visual stimulus "naturally" results in an attenuation of alpha activity (e.g., Gale, Dunkin, and Coles, 1969). Now, under eyes-open conditions, resting EEG shows a cycling between alpha and no-alpha states. Thus, if the onset of the visual stimulus is linked to the production of alpha, the natural cycling between alpha and no-alpha states will be influenced. Mulholland has shown that variability in cycling is reduced by the provision of this type of feedback system and, from a series of studies, has concluded that the systems model shown in Figure 1 is a reasonable way to approach biofeedback phenomena.

One important point should be made about Mulholland's model. The subject is not required to (a) be aware of the contingencies of the feedback or (b) consciously try to influence the feedback. In this respect, Mulholland's research is not directly relevant to the present studies where the subjects are required to invest some cognitive (or other) resources in the generation of alpha. However, the research does point to the importance of the feedback stimulus as a source, not only of information for the subject, but also as an event which exerts a "natural", unconditioned effect on the EEG.

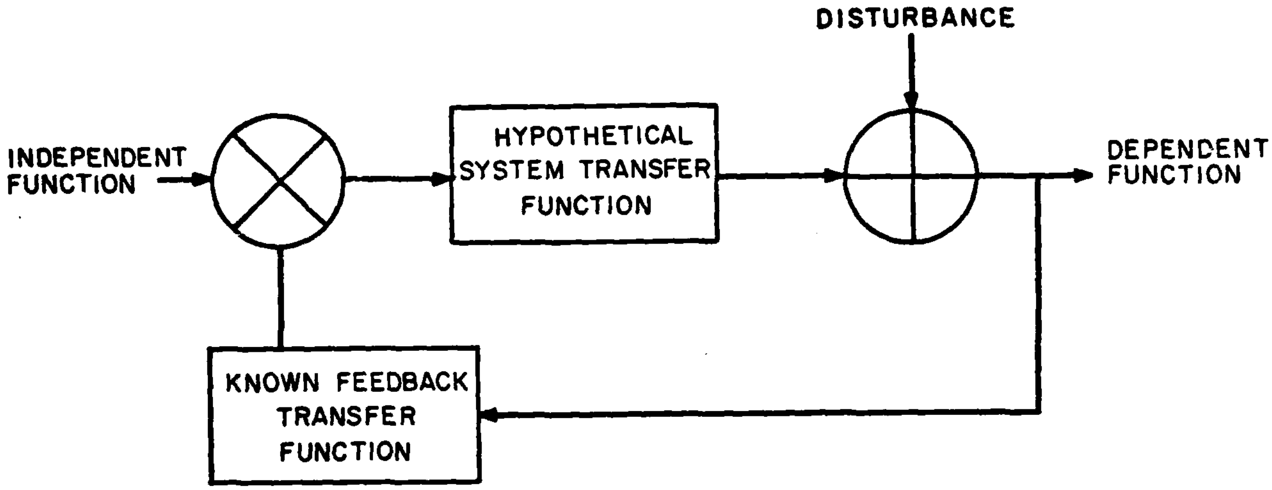


Figure 1. Feedback system with feedforward and feedback (Mulholland, 1977).

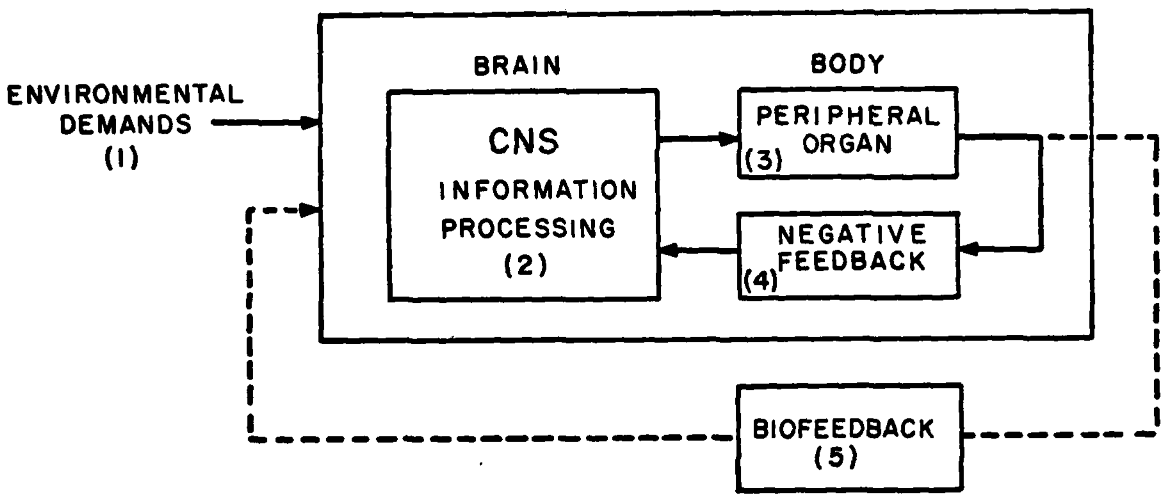


Figure 2. Schwartz's model for biofeedback (Schwartz, 1979).

*Schwartz's systems approach*. Figure 2 shows the model for biofeedback proposed by Schwartz (1979). Strictly, this model applies to biofeedback of peripheral skeletal and autonomic functions. However, it can also be applied to EEG biofeedback. Note that, as in Mulholland's model, an internal negative feedback loop is hypothesized. During biofeedback, an external loop is added (5), and it is the association between external and internal feedback information which presumably leads to improvement in control of the target behavior. However, it should be noted that, since central mechanisms involved in internal monitoring and those involved in processing the external biofeedback information may not be the same, such an association may not lead to enhanced control when external feedback is disconnected.

*A new model of biofeedback*. Figure 3 shows the model of biofeedback that underlies the present research. It borrows from both the Mulholland and Schwartz models, but adds some new concepts from Dinnat (1979) and the authors. It is proposed that a neuro-generator (1) is responsible for the generation of alpha activity (2). The presence of alpha activity gives rise to observable states (3) which can be either provided externally (4 - the feedback signal in the biofeedback experiment) or internally (5). Evidence for internally provided observable states could come from finding that subjects are able to increase alpha activity in the absence of any external feedback. These observable states are monitored by a central monitoring process (6) which may also be required to monitor the external environment (7). As a result of monitoring, the system activates (8) alpha mediators which are connected to the neuro-generator. The activator is also involved in providing resources for cognitive tasks (9). Disruption of the biofeedback system can occur at two levels. First, if environmental stimuli force the monitoring system to switch from the observation of the alpha-

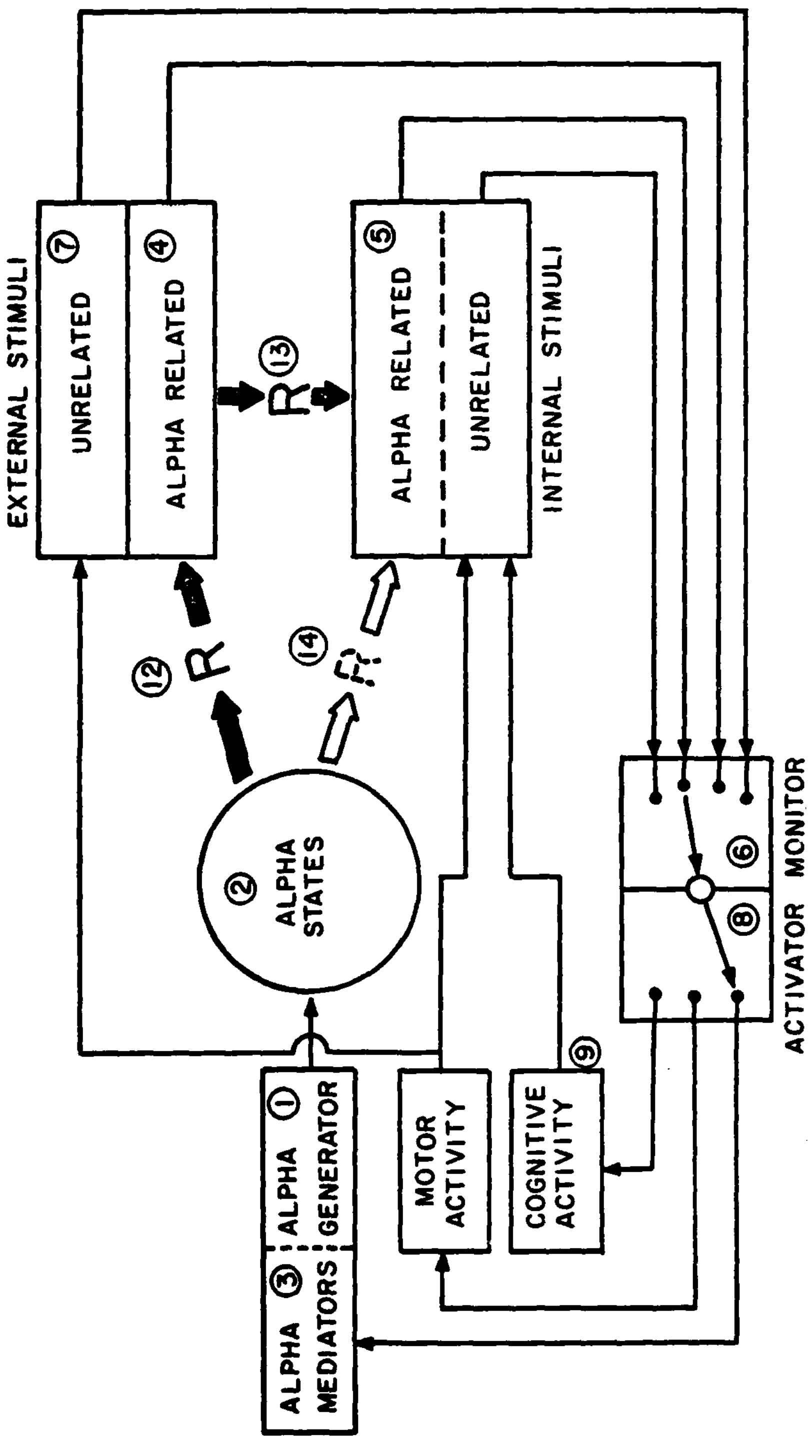


Figure 3. The proposed model of biofeedback.

related states then alpha production must necessarily suffer. Second, if the activating system is involved in providing resources for cognitive tasks, it cannot at the same time activate alpha mediators. Under these conditions then, the production of alpha would suffer. Furthermore, the environmental stimuli may themselves produce a state which is antithetical to alpha production (cf. Mulholland's work on visual stimuli and the occipital EEG).

Note that control of alpha production occurs when the association is made between the mediators, the alpha state and the external observable state (feedback [12]). If the mediators are consciously generated (see below) and are themselves observable internal states (5), then transfer of control from the feedback to the no-feedback situition can occur after internal and external states are associated (13). Controlled generation without feedback would then require that an association between alpha states and alpha-related internal stimuli had been developed (14).

Mediation

Sufficient data is now available to indicate that at least some individuals can gain control of the production of alpha activity. Of central concern here is the question of how this control is achieved -- that is, what are the mediating processes? In the previous section, we noted that interference with the production of alpha activity could be attributable to the draining of resources required for mediation by cognitive activity. Thus, the extent of interference would depend on the degree to which cognitive and mediating activity draw on the same resources.

The question of mediation has been of central concern to many researchers in the biofeedback area. In general, two classes of mediation are identified (Katkin and Murray, 1968) -- somatic and cognitive. Somatic mediation involves

the use of skeletally controlled behavior to generate the desired output, while cognitive mediation involves the use of "thoughts."

The somatic meditors reported by subjects enhancing alpha activity include relaxation (e.g., Brown, 1971; Nowlis and Kamiya, 1970) and "not-focussing" (e.g., Nowlis and Kamiya, 1970; Plotkin, 1976). Relaxation would seem to be especially susceptible to a variety of "noxious" environmental events and associated affective processes (such as stress and anxiety) which produce increases in muscle tension. On the other hand, mediation involving "not-focussing" would be influenced by any situation requiring visual processing.

The cognitive mediators include letting go, floating, awareness "in back," etc. (Nowlis and Kamiya, 1970). Although these subjective descriptions are vague, it is not unreasonable to suppose that any task or situation requiring cognitive activity would disrupt the cognitive mediating process.

## Hypotheses

If the revised model of alpha regulation was representative of a true volitional control system with major cognitive mediation components, then a number of hypotheses could be generated based upon this assumption. Dinnat (1979) proposed a series of such hypotheses, some of which were a direct outgrowth of his original model. These were (1) that performance would stabilize after sufficient training and that all subsequent performance would fall within determinate bounds; (2) in the absence of feedback performance would eventually return to baseline levels; (3) performance with feedback would be superior to performance without feedback; (4) if the feedback sensory mode interferred with alpha production, these effects would be detectable using environmental changes/stimuli in that sensory mode; (5) if the feedback sensory mode did not interfere with alpha production, production performance would be independent of activity

in that sensory channel; (6) alpha generation should be subject to disruption by enviromental distractors in the same way that cognitive tasks were.

If this last hypothesis was substantiated one might be able to infer disruptions of cognitive tasks by environmental stimuli through observation of the disruption of alpha production. A series of experiments, each dependent upon its immediate predecessor, was conducted to evaluate these and other hypotheses concerning the production of alpha activity and the extent to which central mediation of the response might be involved.

# PHASE 1

The evaluation of alpha generation as an index of productivity potential required development in two major areas prior to experimentation. These two aspects of system architecture were hardware devices and software systems.

## Hardware Devices

It was desirable that the measurement system be simple, economical, and transportable for possible future use in the field. These requirements were satisfied through the use of a microprocessor-based computer system with appropriate input/output devices (Figure 4). This consisted of an Apple II+ computer with two floppy disk drives, 12" c.r.t. monitor, and dot-matrix impact printer (graphics capability) using a parallel interface. The system also contained a 16-channel analog-to-digital converter, RS232 serial interface, 48K bytes of memory, and a real-time clock. A smaller monitor was added to allow remote monitoring of results by experimental subjects.

The microprocessor system received processed EEG information (in analog form) from an Autogen 120 Encephalograph Analyzer. It was necessary to both electrically isolate this device from the computer and to scale down the analog outputs of the device. This was accomplished by use of a simple and inexpensive optical interface constructed specifically for the project (see Appendix A for schematic). The moderate nonlinearities (see response curves, Appendix A) inherent in such an unsophisticated device were easily compensated for in the data collection software. The two-channel device proved extremely reliable, requiring only infrequent replacement of the batteries supplying one of the two sources of interface electrical power.

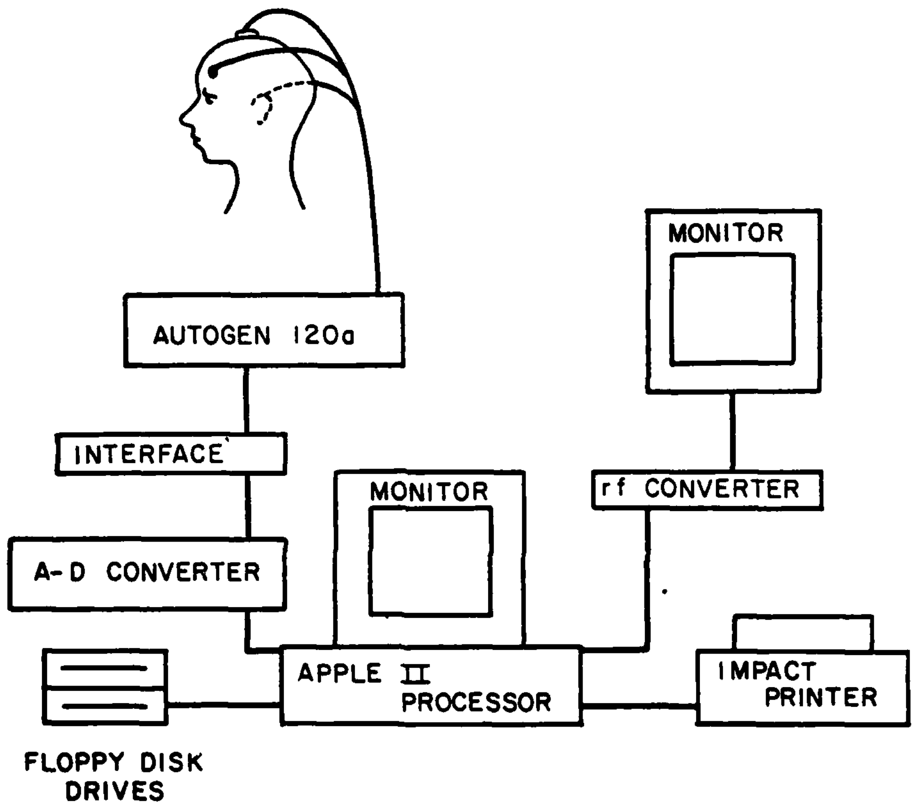


Figure 4. Data collection system hardware configuration.

Software Systems

All data collection and manipulation operations were performed using the microprocessor system in floating-point BASIC. Experimental trials were intermediately stored in memory and transferred to disk at the end of each trial. The software provided not only real-time graphic displays of performance but also the capability of graphic presentation of results at the termination of each trial. Data manipulation software developed for the project provided hard copy of data listings, graphic results, and statistical analyses. The packages also provided multiple overlay capabilities for comparative graphics. Software listings are contained in Appendix B.

Method

The first major phase of experimentation dealt with the questions of performance stability as it affected training requirements and the role of feedback in performance enhancement. Ten subjects, 5 male and 5 female, were selected from among university students responding to advertising for the study. Although these participants were guaranteed minimum wage for the time of their service, most were motivated by the potential of learning to control their brainwave activity. In this respect there was some preselection of subjects inasmuch as they were not conscripted from undergraduate psychology courses as is often the case. These subjects were given a briefing on biofeedback as a general concept and connected to the measurement system using three sponge electrodes. The two active sites measured were left frontal (above the left eye) and midsagital. The reference electrode was placed behind the right ear over the mastoid bone.

Subjects were instructed to seat themselves comfortably, relax, close their eyes, and avoid the use of facial or jaw muscles for a few minutes. After the

subject appeared relatively confortable a two-minute baseline trial was initiated at a signal-amplitude criterion of 30 microvolts. At the conclusion of this trial the subject was instructed to open his/her eyes and look into the center of a large piece of cardboard that was devoid of any distinguishing marks. A baseline was then measured in this eyes-open condition at a criterion of 30 microvolts. This was followed by instruction on the various strategies that might be useful in elevating alpha production. Each subject then received an average of 17 minutes of practice time with auditory feedback (three 5-minute trials with interpolated discussion). Feedback consisted of a tone varying in frequency and amplitude as did the averaged EEG activity while within the bounds of alpha (8 to 13 Hz).

At the end of this instructional period a series of two-minute performance trials was conducted to determine at what point short-term performance reached an asymptote. Criterion for reaching stable performance was set as three consecutive trials on which final percentage scores increased by no more than five percentage points. The dependent measure was percent time in alpha, calculated as time in alpha divided by total time on task. This fraction was continuously recalculated throughout the trial at the rate of six times per second. The mean number of trials required to satisfy this criterion was 3.9 (s.d.= 1.28). This normally ended the first session as overall time in experimentation was usually one hour by this time and some signs of subject fatigue were often evident.

The next segment of performance assessment involved trials to criterion with eyes open and the effects of feedback withdrawal on sustained performance. A baseline in the eyes-open condition was measured and subjects then proceeded as in the first-session criterion trials. These measurements were followed by two series of four-minute trials requiring alpha production without feedback,

both with eyes closed and eyes open. Subjects again used a relatively empty visual field during the eyes-open trials.

Results and Discussion

Figure 5A shows seven superposed criterion trials for subject #1. This is immediately followed by a point-by-point plot of the mean plus and minus one standard deviation for these trials (Figure 5B). These results are generally representative of majority performance on the task, with final performance levels being reasonably close. There is, however, considerable variation at the outset of the trials. This is not suprising due to the nature of the dependent variable and its statistical tendency towards reduced variability as time on task increases. This artifact is illustrated in Figure 5C, showing a plot of hypothetical performance alternating from alpha to no-alpha at 2 Hz (fraction recalculated at 1 Hz). The discontinuity of the function and its rapid bounding are both evident, the discontinuity contributing to maximized variation in the early seconds of the trial and the limiting nature tending to stabilize the resultant in the latter stages. What is interesting in the performance data is that although overall performance did stabilize with repeated trials, the manner in which subjects achieved that final value did not. The final trial in the series for subject #1 is, in fact, the top curve in the early seconds in Figure 5A. This curve clearly falls outside of a standard deviation for a good part of the trail.

The fact that multiple paths exist leading to the same overall performance suggests that there is no stable "production function", underlining the random-burst nature of alpha. It appears that overall alpha production as measured over a specified time period is relatively constant under constant conditions. The distribution of this activity, however, may vary across trials.

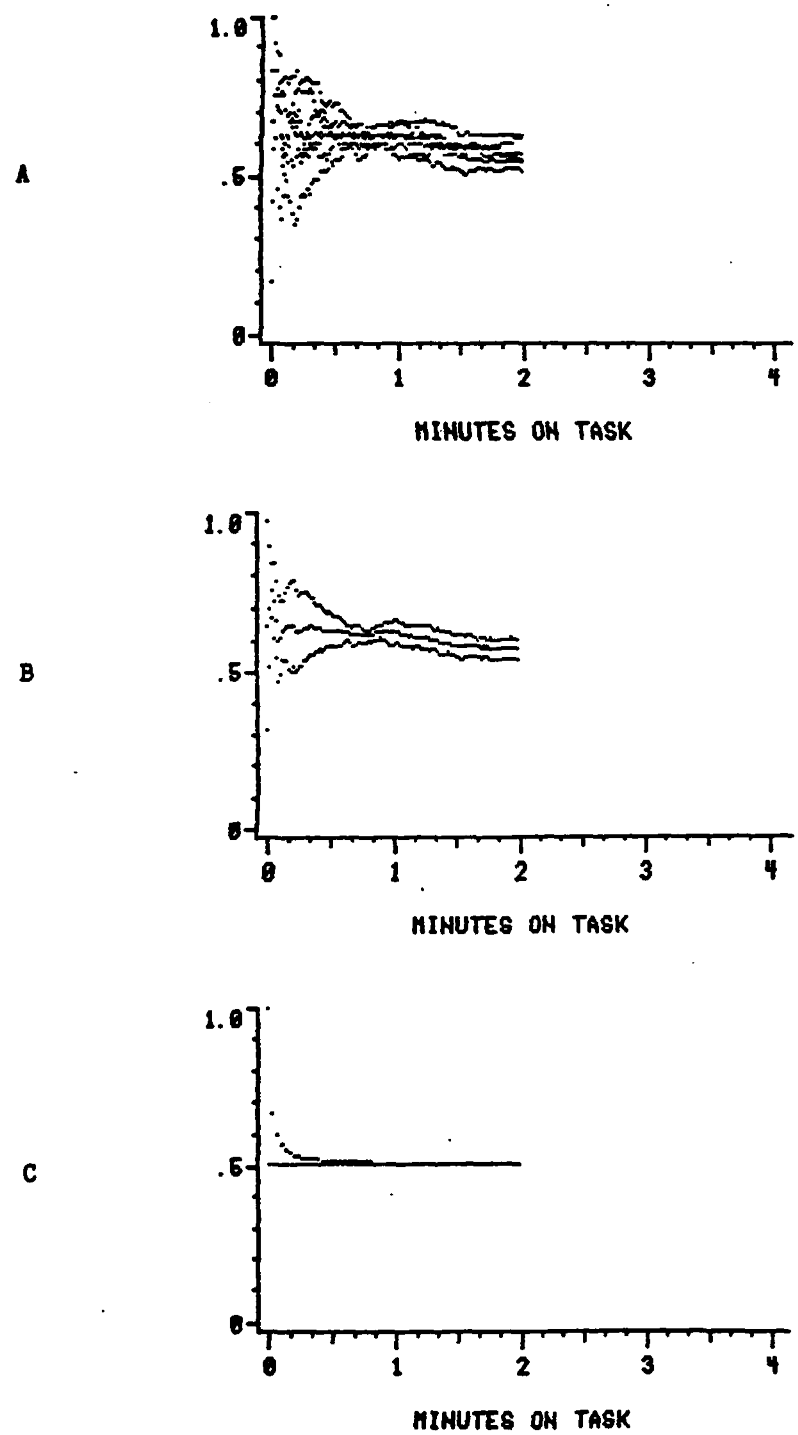


Figure 5. Percent time in alpha by time on task: Superposed trials (A), mean and s.d. (B), and hypothetical data (C).

A second question area involved the function of feedback in facilitating performance. Hypothesis (2), the eventual decay of performance to baseline levels after withdrawal of feedback, was not supported. The ten subjects examined were evenly divided between those whose performance eventually dropped below baseline levels and those whose performance remained above baseline. There had been some concern that performance was not returning to the baseline levels because alpha mediators were being incorporated into each individual's normal relaxation behavior. This was examined for 16 subjects from the Phase 2 section of the study by taking pre- and post-training baselines for each subject. A one-way analysis of variance of percent alpha scores demonstrated no reliable shift in baseline scores ($F(1,15) = 3.72$, $\underline{p} > .05$). A similar analysis was conducted on cycle frequency into and out of alpha. Scores were transformed by log(x) to better meet the assumptions of the test (Myers, 1972). Again, no reliable baseline shift was found ($F(1,15) = 1.37$, $\underline{p} > .05$). Thus training did not reliably affect baseline unintentional performance. (ANOVA summary tables are contained in Appendix C.)

It had also been hypothesized that performance with feedback would be superior to performance without feedback. This question was approached by comparing the average scores from performance trials using feedback with scores from performance trials without feedback. Only the first two minutes of the no-feedback trials were used so that comparisons would be made over equal lengths of trial time. (No reliable differences were found between summary measures for the first two minutes and summary measures for the entire four minutes of the original trial.)

The initial within-subject analysis of variance of percent alpha by both feedback condition and eyes open/closed indicated reliable effects for feed-

back ($F(1,9) = 6.45$, $p < .05$), eyes open/closed ($F(1,9) = 21.6$, $p < .01$), and the interaction of the two $F(1,9) = 8.33$, $p < .025$). This was not unexpected as it has already been demonstrated that alpha generation with eyes open is less than that achievable with eyes closed. The scores were then transformed by baseline scaling to eliminate the effect of eyes open/closed and also transformed by log(x+30) to fit the linear model more accurately. This analysis yielded near-reliable effects for feedback condition ($F(1,9) = 4.73$: $F(1,9)$ at $p(.05) = 5.12$), and the interaction of feedback condition with eyes open/closed ($F(1,9) = 5.03$). The effect of eyes open/closed, as anticipated, was not reliable ($F(1,9) = 1.04$).

The mean of baseline-scaled scores in the eyes-closed condition dropped from 6.3% with feedback to 2.5% without feedback. In the eyes-open condition the same respective means were -11.6% and 2.6%. The means for these conditions are depicted in Figure 6 (converted back to the original units from the transformed means). This approach does make interpretation somewhat more difficult. More seriously, however, this result was quite different from that derived from the unscaled data where reliable decreases were evident from eyes-closed to eyes-open and from feedback to no-feedback conditions. There still remains a reasonable question as to the validity of the second-session baselines taken prior to the no-feedback trials.

Gross departures from normality and differing distributions across cells of the design made the same analysis impractical for cycle frequency. The mean differences, however, were only .17 Hz at the greatest for the raw data and .01 Hz for the baseline-scaled data. There did not, as such, appear to be any consistent or meaningful differences in cycle frequency as a result of feedback or eye-condition manipulations. It should be noted that no differences attri-

butable to sex were detected for the 10 subjects in Phase 1.

One possible explanation for the eyes-open increase from feedback to no-feedback conditions relies on feedback mode as a basis. Given the proposed model, positive feedback would require the cognitive monitor to switch from monitoring internal mediators to processing external feedback. The resultant lapse in mediator supervision could then result in decrements in alpha performance. It is not clear how this process might have have an inverse effect when the eyes are closed. Phase 2 experimentation was directed towards further examining this problem.

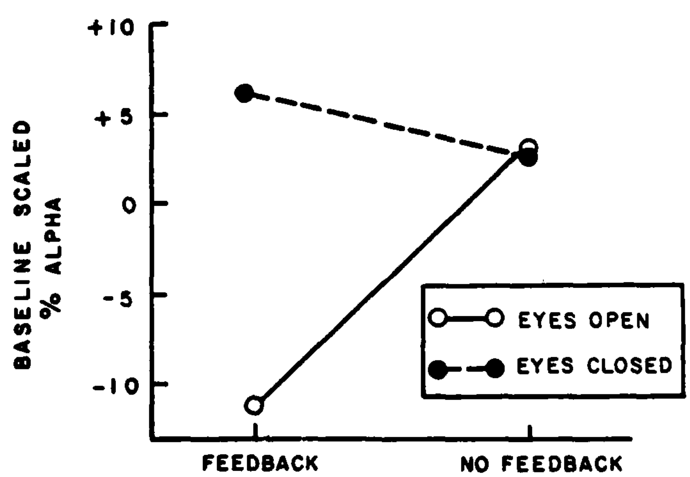


Figure 6. Retransformed condition means: Baseline-scaled percent alpha by feedback and eye conditions.

# PHASE 2

The second phase of experimentation was designed to investigate the effects of feedback mode (auditory/visual) and feedback polarity (positive/negative) upon alpha production. It has already been mentioned that feedback provided through a non-interferring sensory channel would more readily enhance performance. Visual activity is known to inhibit alpha activity, suggesting that auditory or tactile channels are better for the transmission of feedback information. Most tasks of interest where this metric would be applied, however, have some visual components and, as demonstrated earlier, there may exist some interaction between visual/auditory activity and performance.

Two scenarios can be developed using the proposed model operating under either positive or negative feedback respectively. Under positive feedback (stimulus on when alpha produced) the cognitive monitor would be called upon to monitor the feedback stimulus when it appeared, drawing the monitor away from the mediator information. In the absence of this input, the generating processes could wander, leaving the criterion region of performance. The external feedback would then cease, allowing the monitor to again receive mediator information, completing the cycle. This behavior is in accord with what Mulholland (1977) had shown in his report of reduced cycling variation.

Negative feedback (stimulus on when no alpha produced) may, however, have a different function. If we begin in a no-alpha state, the stimulus is on, again drawing the monitor to external events and away from mediator information. The only way to enter criterion alpha production would be through the normal baseline cycling from no-alpha to alpha, turning off the external stimulus.

Once this was accomplished the monitor could then return to receiving mediator information and could remain in this state for as long as it was not called upon to receive other information. This could result in higher variability of cycling. Its projected effects upon actual time in alpha and cycle frequency are unclear and were an object of investigation.

Method

An additional 19 subjects who responded to the solicitation for participants were screened for intentional alpha production. The procedures were the same as those used in the initial stages of Phase 1; initial baselines, training, secondary baselines, and eyes-closed intentional production with feedback. Six of these individuals demonstrated some ability to enhance their alpha production. These individuals returned for a second session during which additional baselines were measured first. Two-minute performance trials were then conducted, in randomized orders, in each of the conditions delineated by a two-by-two factorial within-subject design. Each initial change in feedback modality was accompanied by 2 minutes of practice in that mode prior to performance assessment. The independent variables were feedback modality (auditory/visual) and feedback polarity (positive/negative). The dependent variables were percent time alpha produced and cycle frequency.

A modification of the original analog-to-analog interface provided for either visual (L.E.D.'s) or auditory (digitally generated tone) feedback (positive or negative) (schematics in Appendix A). Auditory feedback was initially presented, in this phase, through light earphones that fitted inside the outer ear (in Phase 1 this was accomplished using a speaker near the subject). These were later replaced by acoustic-tube earphones so that the electromagnetic driving element would not be in proximity to any of the electrodes. Visual feedback was presented

by use of two red L.E.D.'s. These were mounted on the inner surface of a translucent industrial face shield and adjusted to eye level. This provided a homogeneously illuminated background upon which the stimulus could be detected and minimized opportunities for visual search activity.

Results and Discussion

Two-way analyses of variance were conducted on raw and baseline-scaled percent time in alpha (% alpha) and cycle frequency by feedback mode and feedback polarity. All untransformed-data analyses exhibited F-ratios considerably less than 1. Analyses performed on transformed scores (Appendix C) still, at the best, exhibited similar results. Closer examination of the within-cell distributions indicated that normality assumptions had been violated. Transformations did not help because there was serious heterogeneity among the distributions. Had the distributions been nonnormal but similar, distortions of the test would have been minimized.

In view of this problem the Friedman two-way analysis of variance by ranks (Horowitz, 1974) was used to examine the data. The sample was large enough that the sampling distribution of the Friedman test followed the chi-square distribution with 3 degrees of freedom. The critical value for p(.05) was 7.81. Obtained values were 2.6 for % alpha and 2.4 for cycle frequency. The baseline-scaled computations required special chi-square (r) tables for a smaller n (Siegel, 1956), giving a critical value for p(.05) of 7.5. Obtained values were 0.9 for baseline-scaled % alpha and 3.9 for baseline-scaled cycle frequency. Thus, no reliable effects due to treatments were found. This is undoubtedly due to the restricted sample size and high individual variability.

Some other apparently consistent relationships had been observed in the summary data and a decision was made to investigate the correlation between the

dependent variables. The overall correlation (Appendix D) across all subjects and all conditions was $R = .71$ [$t(406) = 20.35$; $p < .001$]. This plot exhibited a marked hook, however, the curve doubling back to high % alpha, low frequency. Subsequent separation of the data by eyes-closed (1,3,5,7,8) and eyes-open (2,4,6,9,10) conditions showed that these nonlinear effects were concentrated in the eyes-closed trials [$R = .596$; $t(245) = 11.63$, $p < .001$]. The eyes-open trials exhibited a very strong linear relationship between the variables [$R = .88$; $t(159) = 23.09$, $p < .001$] ( see Appendix D). Although these correlations were also examined by each of ten conditions, microvolt levels, and subjects, eyes-open versus eyes-closed appeared to be the greatest defining contrast. This was undeniably due to the alpha blocking found with visual activity, reducing variability in that condition.

This correlation between the dependent variables has implications for multivariate metrics that were earlier thought possible. Preliminary data collected on and analyzed from strip-chart recordings suggested that these two variables had a certain measure of independence. Examination of alpha activity during various tasks (mental arithmetic, reading, visual tracing, monitoring spoken text for target words) suggested that some tasks that could not be differentiated by % alpha alone could be differentiated by concurrent examination of cycle frequency. If the high positive correlation of these two variables extends beyond the confines of this particular experimental paradigm, then the use of these variables in a multivariate discrimination scheme may not be realized.

# CONCLUSIONS

Although the model of biofeedback and electrocortical activity control proposed herein was consistent with previous research findings, additional confirmation of its validity was not obtained from the present study. It is difficult to determine which factors were most influential in producing this outcome. Certainly, the presence of tremendous variability between and within subjects coupled with the low incidence of alpha production enhancement makes this particular metric an unattractive one. While it appears to have a high degree of sensitivity to enviromental changes, it is, perhaps, overly sensitive and thus unstable. More productive metrics for the evaluation of environmental impacts on behavior might be developed from evoked cortical potentials, physiological measures, or some combination thereof.

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# APPENDIX A:

# SCHEMATIC DIAGRAMS

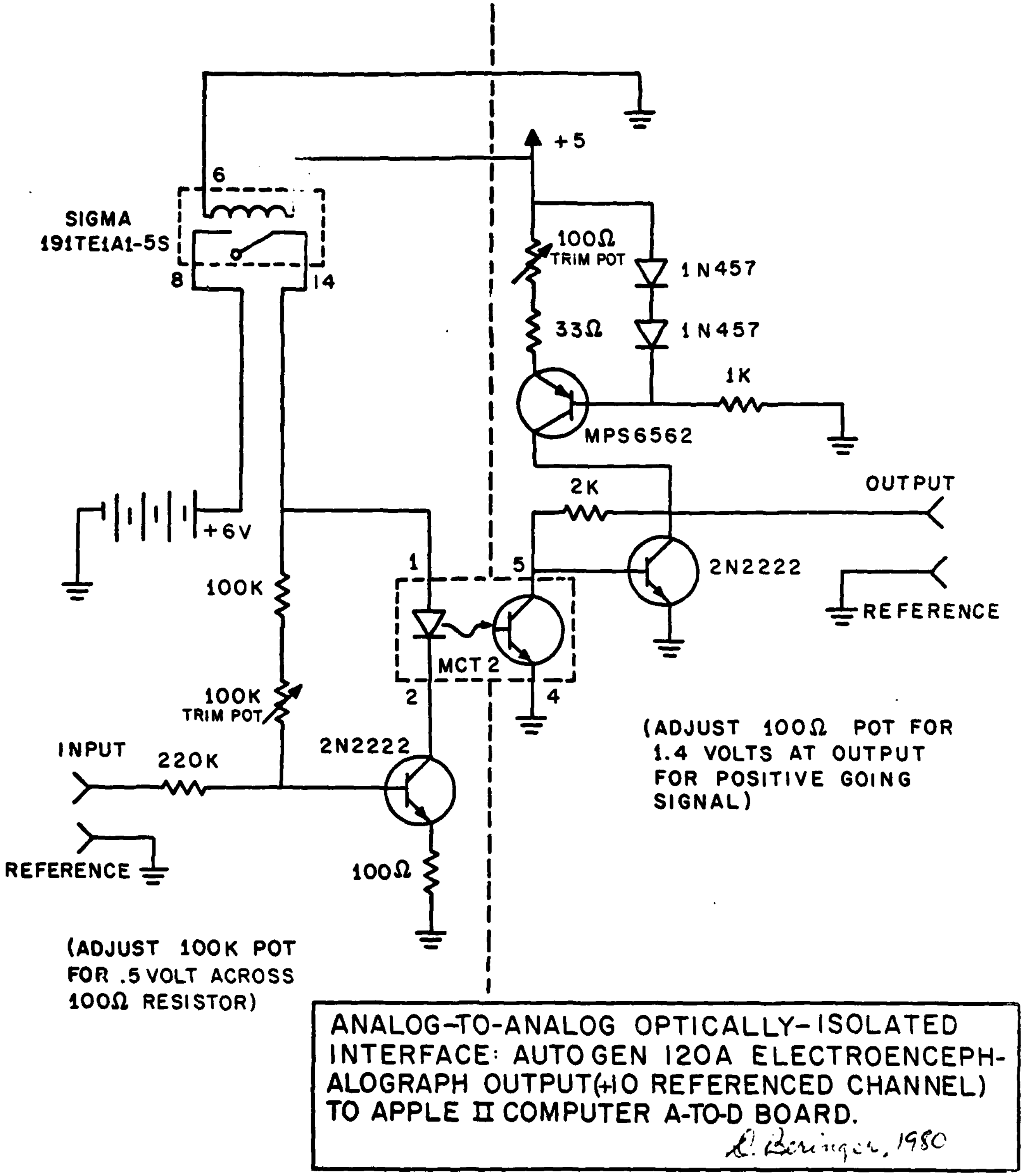


Figure 7. Schematic diagram: Analog-to-analog interface, channel 1.

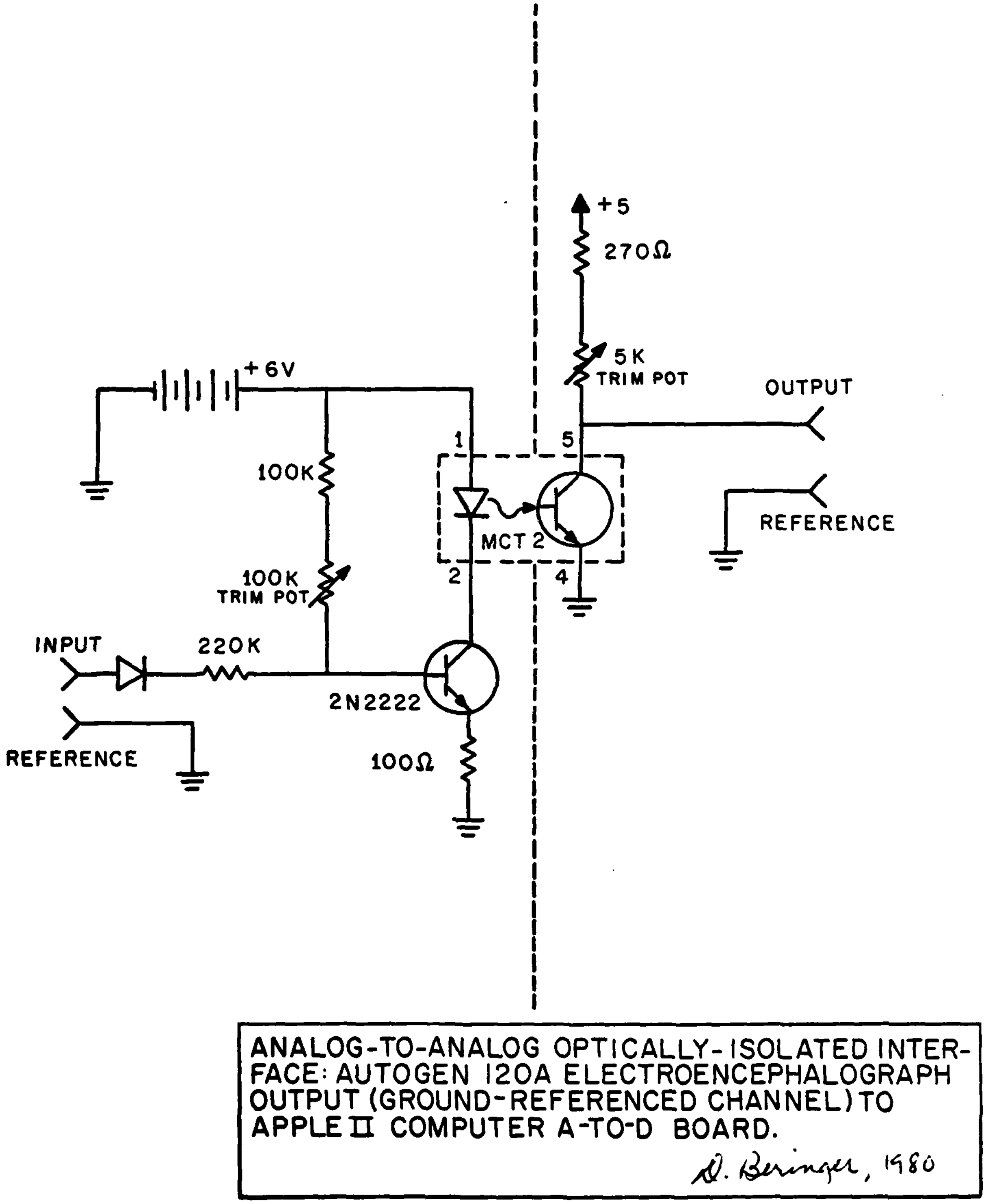


Figure 8. Schematic diagram: Analog-to-analog interface, channel 2.

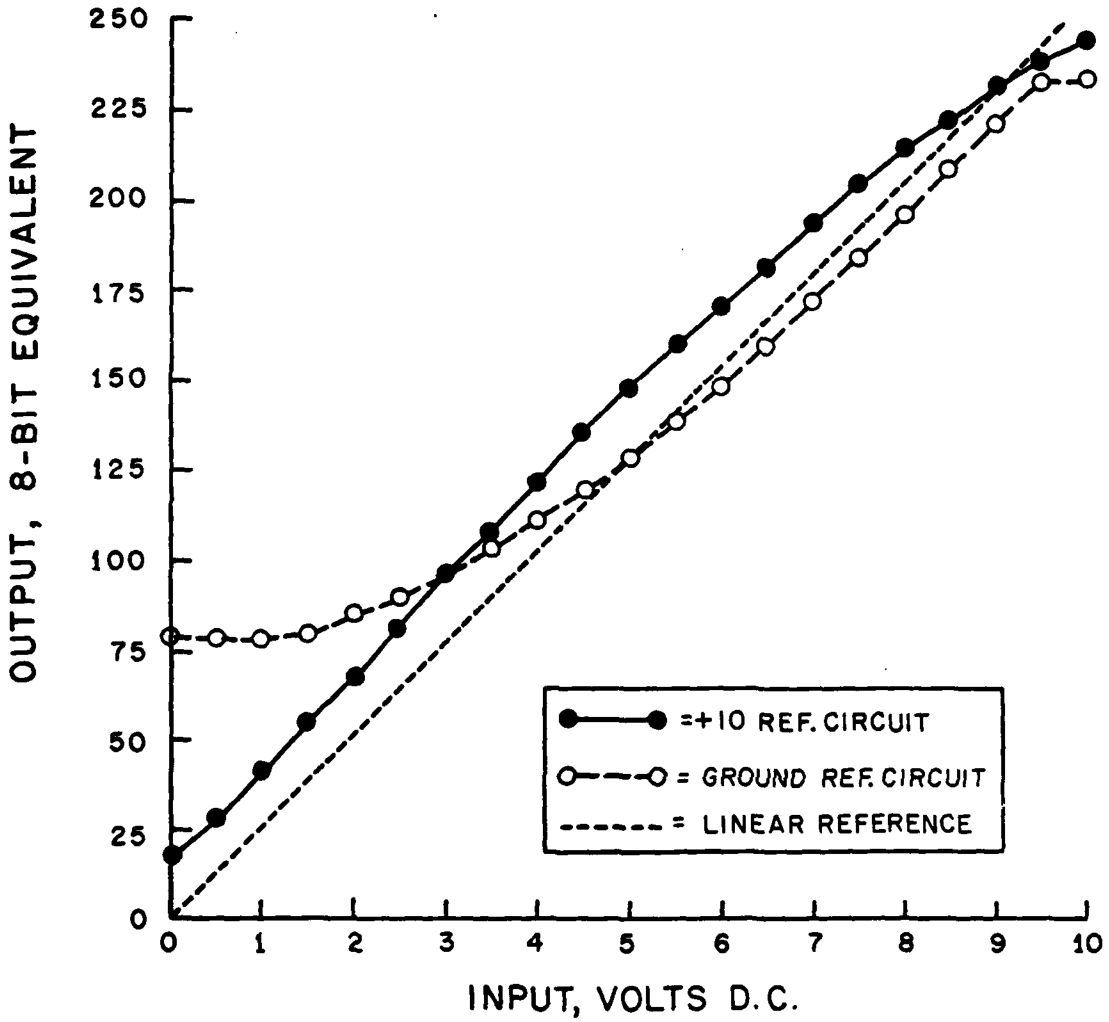


Figure 9. Analog-to-analog interface input/ouput characteristics.

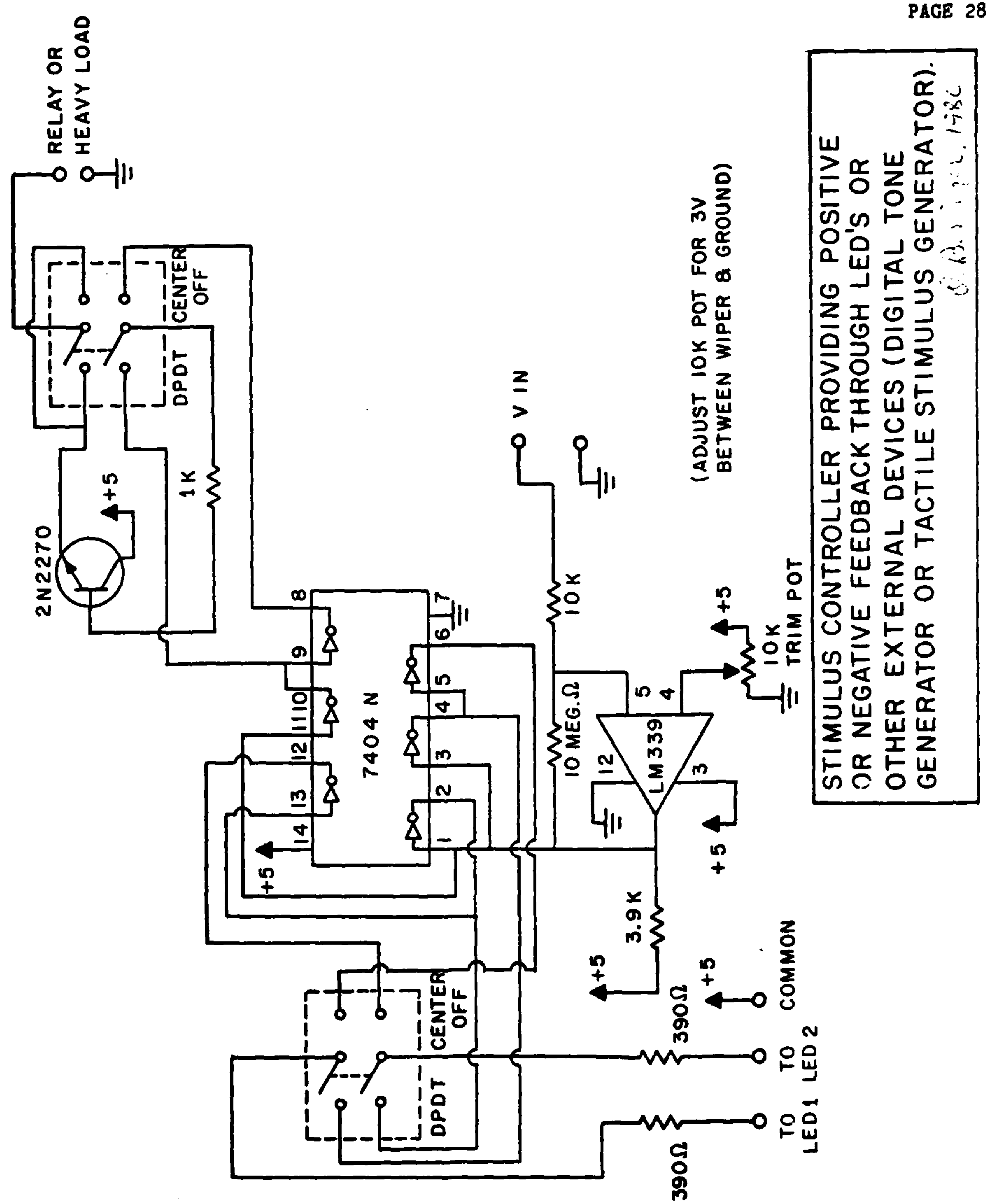


Figure 10. Schematic diagram: Digital stimulus controller.

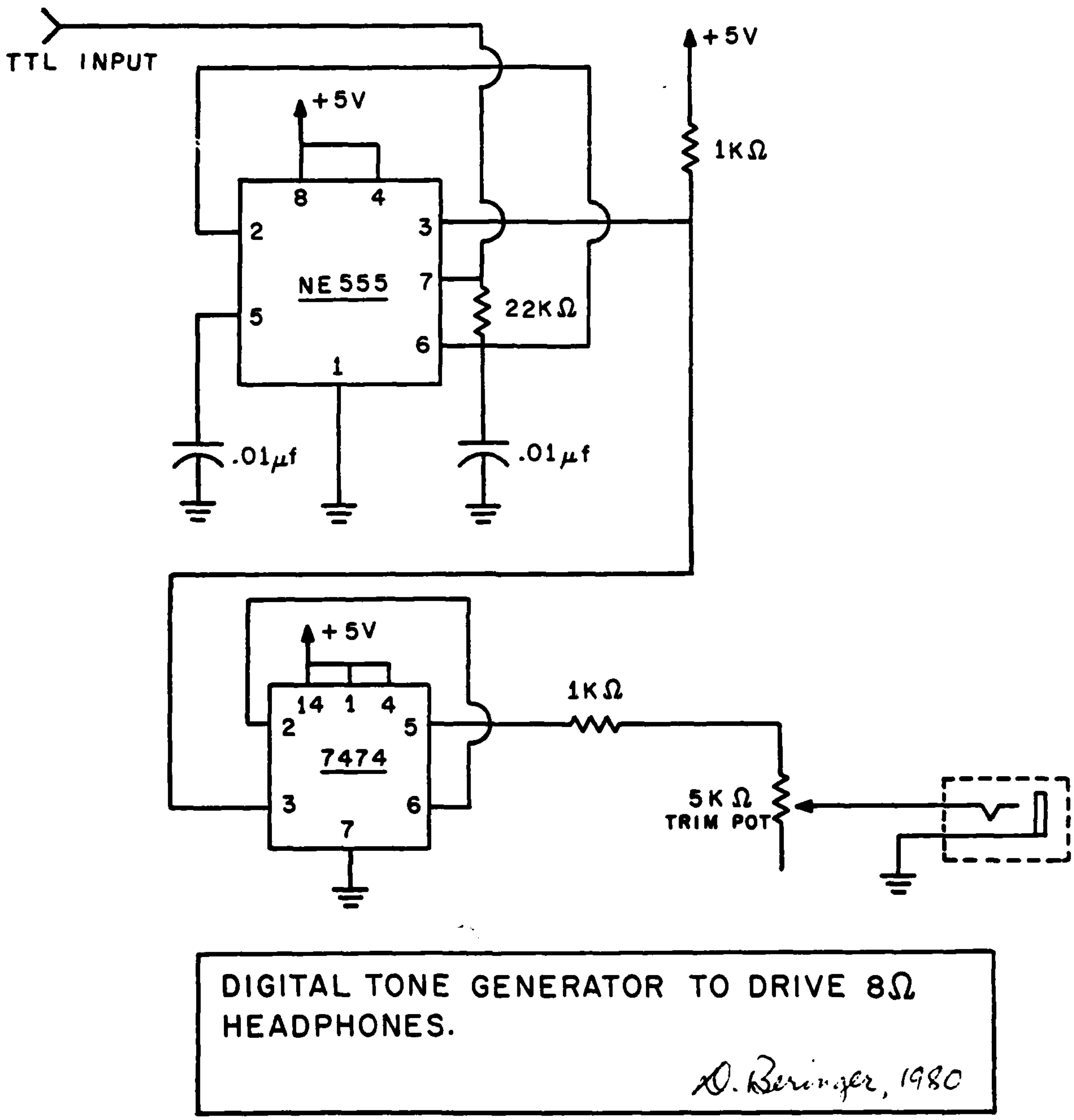


Figure 11. Schematic diagram: Digital tone generator.

# APPENDIX B:

# SOFTWARE LISTINGS

```
]PRINT DATA COLLECTION AND MANIPULATION PROGRAM

?SYNTAX ERROR
]LIST

1  DIM PC%(300),SU%(300),FCOUNT%(300),WF%(60)
3 DSTART = 24586:WSTART = 25500:A =  - 15872: REM  A VALUE FOR A/D IN SLOT
   2
4  PRINT : PRINT "LOADING WRITE FLAGS"
5  HIMEM: 16383:D$ =  CHR$ (4):SSTART = 25572
6  PRINT D$;"BLOAD WFLAG,A25500": REM  SOFTWARE PROTECTION TO PREVENT OVER
     WRITES
7 SBNUM = 0
8  CALL 62450: TEXT : HOME :X =  FRE (0)
9  PRINT "1 FOR DATA COLLECTION,"
10  INPUT "2 FOR DISK RETRIEVE. ";G
11  IF G = 2 THEN  GOTO 3000
12  GOSUB 9000
13  HGR2
14 SAMPS = 0:DEXER = 0:SCREENS = 0:SY = 0:IA = 0:S1 = 0:COUNT = 0:OFLAG =
    0
15  CALL 62450
16 XM = 1: GOSUB 7000
18  FOR I = 10 TO 270
19 SFLAG = 0:SAMPS = SAMPS + 1
20  POKE A + 1,6
21 IN =  PEEK (A): IF IN < 85 AND IA = 0 THEN  GOTO 20
22  POKE A + 1,7: IF IA = 0 THEN IA = 1
23 PER =  PEEK (A)
24  GOSUB 100
25 PY = 128 - (PER / 2)
26 OY = 128 + ((IN - 75) / 50)
27  IF IN > 85 THEN S1 = S1 + 1:SFLAG = 1
28 SY = 128 - (128 * (S1 / ((I - 9) + (SCREENS * 261))))
29  IF SY > 191 OR SY < 0 THEN  GOTO 300
30  HCOLOR= 7: HPLOT I,PY
31  HPLOT I,128 TO I,OY
32  HPLOT I,SY
33  IF SFLAG = OFLAG THEN  GOTO 40
34 COUNT = COUNT + 1:OFLAG = SFLAG
40  IF SAMPS = 6 THEN  GOSUB 190
50  NEXT I:SCREENS = SCREENS + 1
51  IF SCREENS < 3 * MINS THEN  GOTO 15
52  GOTO 1000
100   IF PER < 28 THEN PER = PER - 18: GOTO 110
101   IF PER < 193 THEN PER = PER - 13: GOTO 110
102   IF PER < 213 THEN PER = PER - 10: GOTO 110
103   IF PER < 221 THEN PER = PER - 5: GOTO 110
104   IF PER < 230 THEN  GOTO 110
105   IF PER < 237 THEN PER = PER + 5: GOTO 110
106 PER = PER + 10
107   REM  SOFTWARE COMPENSATION FOR NONLINEAR ANALOG INPUT
110   RETURN
190 D1 =  INT (PER / 2.55):D2 = (PER / 2.55)
195   IF (D2 - D1) > .49 THEN D1 = D1 + 1
200 PC%(DEXER) = D1
203 D1 =  INT ((128 - SY) / 1.28):D2 = ((128 - SY) / 1.28)
206   IF (D2 - D1) > .49 THEN D1 = D1 + 1
210 SU%(DEXER) = D1
220   IF DEXER = 0 THEN FCOUNT%(DEXER) = COUNT: GOTO 230
225 FCOUNT%(DEXER) = COUNT - OCOUNT
230 DEXER = DEXER + 1
231 OCOUNT = COUNT
235 SAMPLE = 0
240   IF DEXER > (60 * MINS) - 1 THEN  GOTO 1000
250   RETURN
300   TEXT
310   PRINT "SY = ";SY
320   PRINT "SCREENS = ";SCREENS
330   INPUT "2 TO CONTINUE, 1 TO QUIT";G
340   IF G = 2 THEN  GOTO 13
1000   CALL 62450: TEXT
1002   PRINT  CHR$ (7): PRINT  CHR$ (7)
1018   PRINT : PRINT "TRIAL CONCLUDED": PRINT
1019   PRINT "(1) LIST DATA (TABLE/GRAPH)": PRINT
1020   PRINT "(2) RECOLLECT DATA (NO STORAGE)": PRINT
1021   INPUT "(3) SEND DATA TO DISK ";G
1030   IF G = 2 THEN  CALL 62450:RC = 1: GOTO 12
1035   IF G = 3 THEN  GOTO 2000
1040   GOTO 3092
```

```
1050  CALL 62450: TEXT
1051  GOSUB 9800
1052  INPUT "LIST(L) OR NEXT ID (N)?";A$
1053  IF A$ = "N" THEN Z = Z + 1: GOTO 3013
1055 BZ = 0
1059 CZ = BZ + 19
1060  FOR DEXER = BZ TO CZ
1070  PRINT PC%(DEXER);"    ";SU%(DEXER);"    ";FCOUNT%(DEXER)
1080  NEXT DEXER: PRINT
1090  INPUT "RETURN TO CONTINUE";A$: PRINT
1110 BZ = BZ + 20
1120  IF BZ < 60 * MINS THEN  GOTO 1059
1140  PRINT : PRINT "LISTING ENDED": PRINT
1150  PRINT "1 TO LIST AGAIN"
1152  PRINT "2 TO RUN PROGRAM AGAIN"
1153  PRINT "3 TO SEND TO DISK"
1154  INPUT "9 TO CLEAR RECORD PROTECTION";G
1160  IF G = 1 THEN  GOTO 3092
1165  IF G = 3 THEN  GOTO 2000
1166  IF G = 9 THEN  GOSUB 5000: GOTO 1150
1170  GOTO 8
2000  CALL 62450
2001  GOSUB 9800
2002  PRINT : INPUT "RETURN TO SEND TO DISK";A$
2003  HOME : PRINT "CHECKING FILES..."
2004  FOR I = 0 TO 59
2005 WF%(I) =  PEEK (WSTART + I)
2006  NEXT I
2007 I = 0
2008  IF WF%(I) = 0 THEN  GOTO 2015
2009 I = I + 1: IF I > 59 THEN  GOTO 2011
2010  GOTO 2008
2011  PRINT "ALL RECORDS FILLED"
2012  INPUT A$: GOTO 1000
2015 WF%(I) = 1:Z = I: POKE (WSTART + I),1
2016  CALL 62450: HOME : PRINT "SENDING TO FILE B";Z
2040  FOR I = 0 TO (60 * MINS) - 1
2050  POKE (DSTART + (3 * I)),PC%(I)
2051  POKE (DSTART + 1 + (3 * I)),SU%(I)
2052  POKE (DSTART + 2 + (3 * I)),FCOUNT%(I)
2060  NEXT I
2061  POKE 24576,SBNUM
2062  POKE 24577,CDN
2063  POKE 24578,TL
2064  POKE 24579,DAY
2065  POKE 24580,MTH
2066  POKE 24581,YEAR
2067  POKE 24582,HOUR
2068  POKE 24583,MNTS
2069  POKE 24584,(MINS * 10)
2070  POKE 24585,MVOLTS
2071  PRINT D$;"BSAVE B";Z;",A";DSTART - 10;",L";(180 * MINS) + 10
2075  PRINT D$;"BSAVE WFLAG,A25500,L60"
2090  PRINT : PRINT "TRANSMISSION COMPLETE": PRINT
2092  PRINT "1 TO RETRIEVE AND LIST,"
2093  INPUT "2 TO COLLECT DATA AGAIN.";G
2094  IF G = 2 THEN  GOTO 8
2099  CALL 62450
3000  PRINT
3004  PRINT : PRINT "1 FOR SINGLE RECORD"
3005  PRINT "2 FOR OVERLAYS "
3006  INPUT "3 FOR STAT OPTIONS ";G
3007  IF G = 2 THEN  GOTO 6000
3008  IF G = 3 THEN  GOTO 3500
3012  INPUT "FILE NUMBER (0-59): ";Z
3013  PRINT : PRINT "ACCESSING FILE B";Z
3030  GOSUB 9500
3040  IF ER = 1 THEN  PRINT "FILE EMPTY":ER = 0: GOTO 3012
3090  PRINT : PRINT "DATA RETRIEVED": PRINT
3092  PRINT "1 FOR TABLE LISTING,
3093  INPUT "2 FOR GRAPH.";G
3094  IF G = 1 THEN  GOTO 1050
3100  HGR2 : HCOLOR= 7
3110 XM = 0: GOSUB 7000
3129 G = 0: GOSUB 8000
3200  INPUT A$: CALL 62450: HOME : TEXT
3220  INPUT "PRESS RETURN FOR CYCLE FREQUENCY ";A$
3230  HGR2
3240 XM = 0: GOSUB 7000
3250  FOR I = 0 TO (60 * MINS) - 1
```

```
3260 FR = FCOUNT%(I)
3280  HCOLOR= 2: HPLOT I + 10,128 TO I + 10,128 - (6.4 * FR)
3290  NEXT I
3300  INPUT A$: HOME : TEXT
3310  CALL 62450: GOTO 1150
3500  REM  *STAT ROUTINE*
3505  HOME : PRINT "PROCESS FILES OPTION:"
3510  PRINT : PRINT "(1) SHOW TRIAL AND MEAN, SD "
3515  PRINT : INPUT "(2) ADD FILES TO STAT BASE";G
3520  IF G = 2 THEN  GOSUB 4000: GOTO 3004
3530  HGR2 : HCOLOR= 7:XM = 0: GOSUB 7000
3540  HCOLOR= 1: GOSUB 8000: HCOLOR= 2
3550  PRINT D$;"BLOAD BSTAT,A25561"
3555  FOR I = 0 TO (60 * MINS) - 1
3560 N =  PEEK (SSTART + (3 * I)): IF N = 0 THEN  GOTO 3610
3565 XSUM =  PEEK (SSTART + 1 + (3 * I))
3570 X2SUM =  PEEK (SSTART + 2 + (3 * I))
3575 XBAR = (XSUM / N) * 10
3580 SDEV = 10 * ( SQR ((N * X2SUM) - (XSUM ↑ 2))) / N
3585 S1 = XBAR + SDEV: IF S1 > 100 THEN S1 = 100
3590 S2 = XBAR - SDEV: IF S2 < 0 THEN S2 = 0
3595  HPLOT I + 10,128 - (1.28 * S1)
3600  HPLOT I + 10,128 - (1.28 * S2)
3605  NEXT I
3610  INPUT A$:X =  FRE (0)
3615  CALL 62450: HOME : TEXT
3620  PRINT "(1) TO ADD THIS TRIAL TO SUMMARY STATS"
3621  PRINT "    (LAST FILE ADDED = "; PEEK (25561);"  )"
3622  PRINT "    (THIS FILE IS #";Z;")"
3625  PRINT : PRINT "(2) TO RETURN TO LISTING OPTIONS"
3630  PRINT : INPUT "(3) TO RETURN TO DATA COLLECTION ";G
3635  IF G = 3 THEN  GOTO 8
3640  IF G = 2 THEN  GOTO 3004
3645 RC = 1: GOSUB 4000: GOTO 8
4000  REM  *ADD FILES TO STAT DATABASE*
4002  IF RC = 1 THEN RC = 0:TR = Z:UR = Z: GOTO 4035
4005  PRINT : PRINT "ADD TO STAT DATABASE"
4010  PRINT : INPUT "1ST FILE: ";TR
4015  PRINT : INPUT "LAST FILE: ";UR
4020  IF UR < TR THEN UR = TR
4025  PRINT "ACCESSING DATA BASE"
4030  PRINT D$;"BLOAD BSTAT,A25561"
4035  FOR K = TR TO UR
4040  PRINT "ACCESSING FILE ";K:Z = K: GOSUB 9500
4045  IF ER = 1 THEN  PRINT "EMPTY FILE ENCOUNTERED": PRINT : GOTO 4080
4047  PRINT "FILE ";K;" LOADED"
4050  FOR J = 0 TO (60 * MINS) - 1
4055  POKE (SSTART + (3 * J)),( PEEK (SSTART + (3 * J))) + 1
4060  POKE (SSTART + 1 + (3 * J)),( PEEK (SSTART + 1 + (3 * J))) + (SU%(J)
      / 10)
4065  POKE (SSTART + 2 + (3 * J)),( PEEK (SSTART + 2 + (3 * J))) + ((SU%(J
     ) / 10) ↑ 2)
4070  NEXT J: PRINT "FILE ";K;" ADDED": PRINT
4075  NEXT K
4080  PRINT "SAVING LAST I.D."
4085  POKE 25561,K
4090  FOR I = 24576 TO 24585
4095  POKE (I + 986), PEEK (I)
4100  NEXT I: PRINT
4105  PRINT "RETURNING TO STAT FILE"
4110  PRINT D$;"BSAVE BSTAT,A25561,L911"
4115  PRINT : PRINT "COMPLETED:"
4120  PRINT "(1) TO ADD MORE"
4125  INPUT "(2) TO EXIT ";G
4130  IF G = 1 THEN  GOTO 4005
4135  RETURN
5000  REM  CLEAR FILE PROTECTION
5005  PRINT : PRINT "CLEAR FILE PROTECTION:"
5010  PRINT : INPUT "FROM (1ST FILE): ";G1
5020  PRINT : INPUT "TO (2ND FILE): ";G2
5021  IF G2 < G1 THEN I = G1:G1 = G2:G2 = I
5030  FOR I = G1 TO G2
5040  POKE (WSTART + I),0
5050  NEXT I: PRINT D$;"BSAVE WFLAG,A25500,L60"
5060  CALL 62450: HOME
5070  RETURN
6000  PRINT : PRINT "VARIABLES: 1 = OVERALL %"
6020  PRINT : PRINT "           2 = INSTANTANEOUS %"
6025  PRINT : INPUT "           3 = CYCLE FREQUENCY ";G
6040  PRINT : INPUT "1ST FILE: ";TR
```

```
6060  PRINT : INPUT "2ND FILE: ";UR
6080  PRINT : PRINT "ACCESSING VARIABLE ";G
6085  PRINT "       FILES ";TR;" & ";UR
6087 Z = TR
6100  GOSUB 9500
6110  IF ER = 1 THEN  PRINT "FILE EMPTY":ER = 0: GOTO 6040
6150  HGR2 : CALL 62450
6155  HCOLOR= 7:XM = 0: GOSUB 7000
6160  HCOLOR= 1: GOSUB 8000
6170 Z = UR: GOSUB 9500
6190  IF ER = 1 THEN  TEXT : PRINT "FILE EMPTY":ER = 0: GOTO 6040
6230  HCOLOR= 2: GOSUB 8000
6240  INPUT A$: CALL 62450: HOME : TEXT
6260  PRINT "1 FOR MORE OVERLAYS,"
6270  INPUT "2 TO EXIT. ";G
6280  IF G = 1 THEN  GOTO 6000
6290  GOTO 8
7000  HCOLOR= 7
7010  HPLOT 5,0 TO 5,131 TO 270,131
7020  FOR I = 0 TO 10
7030 J = 3: IF I = 0 OR I = 5 OR I = 10 THEN J = 0
7040  HPLOT J,12.8 * I TO 5,12.8 * I
7050  NEXT I
7055  IF XM = 1 THEN  GOTO 7070
7060  FOR I = 0 TO 3
7061  FOR J = 0 TO 5:K = 2
7062  IF J = 0 THEN K = 7
7063  IF J = 3 THEN K = 4
7064 QX = (I * 60) + (J * 10) + 10
7065  HPLOT QX,131 TO QX,131 + K
7066  NEXT J
7067  NEXT I
7070  RETURN
8000  FOR I = 0 TO (60 * MINS) - 1
8001  IF G = 1 THEN  GOTO 8010
8002  IF G = 2 THEN  GOTO 8020
8003  IF G = 3 THEN  GOTO 8030
8010  IF G = 0 THEN  HCOLOR= 1
8012 SY = 128 - (1.28 * SU%(I))
8013  IF SY < 0 THEN SY = 0
8014  HPLOT I + 10,SY
8015  IF G > 0 THEN  GOTO 8050
8020  IF G = 0 THEN  HCOLOR= 2
8021 PY = 128 - (1.28 * PC%(I))
8022  IF PY < 0 THEN PY = 0
8023  HPLOT I + 10,PY
8024  IF G > 0 THEN  GOTO 8050
8030  IF G = 0 THEN  HCOLOR= 7
8031 FR = FCOUNT%(I)
8033  IF G = 0 THEN  HPLOT I + 10,128 TO I + 10,128 - (FR): GOTO 8050
8035  HPLOT I + 10,128 - (6.4 * FR)
8050 G = G
8095  NEXT I
8099  RETURN
9000  REM  SUBROUTINE FOR ID & TIME
9001  IF RC = 1 THEN RC = 0: GOTO 9050
9005  PRINT : INPUT "SUBJECT NUMBER: ";SBNUM
9010  PRINT : INPUT "CONDITION: ";CDN
9020  PRINT : INPUT "TRIAL: ";TL
9030  PRINT : INPUT "TRIAL LENGTH (MINUTES): ";MINS
9036  IF MINS > 4 THEN MINS   4
9037  IF MINS < 1 THEN MINS = 1
9040  PRINT : INPUT "AMPLITUDE IN MVOLTS: ";MVOLTS
9050  PRINT : INPUT "HIT RETURN TO START";A$
9060  REM  GET THE TIME & DATE
9070  PRINT D$;"IN#4": REM  INPUT TO CLOCK
9100  INPUT " ";T$: REM  GET TIME
9110  PRINT D$;"IN#0": REM  IN TO KEYBOARD
9130 MTH$ =  LEFT$ (T$,2)
9140 DAY$ =  MID$ (T$,4,2)
9150 HOUR$ =  MID$ (T$,7,2)
9160 MNTS$ =  MID$ (T$,10,2)
9170 MTH =  VAL (MTH$): REM  DEC FROM STRING
9180 DAY =  VAL (DAY$)
9190 HOUR =  VAL (HOUR$)
9200 MNTS =  VAL (MNTS$):YEAR = 80
9300  RETURN
9500  REM  SUBRT TO RETRIEVE A FILE
9501  REM  NEEDS "Z" FROM MAIN PROGRAM
9505  IF  PEEK (WSTART + Z) = 0 THEN ER = 1: GOTO 9580
```

```
9510  PRINT D$;"BLOAD R";Z;",A";DSTART - 10
9511 SBNUM =  PEEK (24576)
9512 CDN =  PEEK (24577)
9513 TL =  PEEK (24578)
9514 DAY =  PEEK (24579)
9515 MTH =  PEEK (24580)
9516 YEAR =  PEEK (24581)
9517 HOUR =  PEEK (24582)
9518 MNTS =  PEEK (24583)
9519 MINS = ( PEEK (24584)) / 10
9520 MVOLTS =  PEEK (24585)
9530  FOR I = 0 TO (60 * MINS) - 1
9540 PC%(I) =  PEEK (DSTART + (3 * I))
9550 SU%(I) =  PEEK (DSTART + 1 + (3 * I))
9560 FCOUNT%(I) =  PEEK (DSTART + 2 + (3 * I))
9570  NEXT I
9580  RETURN
9800  REM  ID DISPLAY SUBROUTINE
9805  PRINT : PRINT "RECORD# ";Z
9810  PRINT : PRINT "SUBJECT # ";SBNUM
9820  PRINT : PRINT "DATE: ";MTH;"/";DAY;"/";YEAR
9830  PRINT
9833  IF MNTS > 9 THEN  PRINT "TIME: ";HOUR;":";MNTS: GOTO 9840
9836  PRINT "TIME: ";HOUR;":0";MNTS
9840  PRINT : PRINT "CONDITION: ";CDN
9850  PRINT "TRIAL NUMBER: ";TL
9860  PRINT
9866  PRINT "LENGTH: ";MINS;" MINUTES"
9868  PRINT "LEVEL = ";MVOLTS;" MICROVOLTS"
9870  INPUT A$
9880  RETURN
```

```
?SYNTAX ERROR
]LIST

1 D$ =  CHR$ (4)
2  CALL 62450: PRINT "LOADING FILE INFORMATION"
3 DSTART = 24586:WSTART = 25500:SSTART = 25573
5  HIMEM: 16384
6  PRINT D$;"BLOAD WFLAG,A25500,D2":SBNUM = 0
8  CALL 62450: TEXT : HOME :X =  FRE (0): GOTO 3000
1050  CALL 62450: TEXT : GOSUB 9800
1051  PRINT : PRINT "SAMPLE / INST% / CUM% / FREQ ": PRINT
1055 BZ = 0
1059 CZ = BZ + 19
1060  FOR DEXER = BZ TO CZ
1061 A1 =  PEEK (DSTART + (3 * DEXER)):A2 =  PEEK (DSTART + 60 + (3 * DEXE
     R))
1062 B1 =  PEEK (DSTART + 1 + (3 * DEXER)):B2 =  PEEK (DSTART + 61 + (3 *
     DEXER))
1063 C1 =  PEEK (DSTART + 2 + (3 * DEXER)):C2 =  PEEK (DSTART + 62 + (3 *
     DEXER))
1065  IF CP = 0 THEN  GOTO 1072
1070  PRINT  SPC( 2);DEXER + 1;")"; SPC( 5);A1; SPC( 6);B1; SPC( 6);C1; SPC(
     12);DEXER + 61;")"; SPC( 5);A2; SPC( 6);B2; SPC( 6);C2
1071  GOTO 1080
1072  PRINT  SPC( 2);DEXER + 1;")"; SPC( 5);A1; SPC( 6);B1; SPC( 6);C1
1080  NEXT DEXER
1081  IF CP = 1 THEN  GOTO 1091
1082  PRINT
1090  INPUT "RETURN TO CONTINUE";A$
1091 BZ = BZ + 20: IF CP = 0 THEN  PRINT
1095  IF CP = 1 THEN  GOTO 1120
1096  IF BZ < 60 * MINS THEN  GOTO 1059
1097  GOTO 1140
1120  IF BZ = (60 * (MINS - 1)) THEN  GOTO 1140
1122  IF BZ = 60 THEN BZ = 120
1124  IF BZ = 120 THEN  PRINT  CHR$ (12): PRINT : PRINT : PRINT : PRINT  SPC(
     70);"PAGE 2": PRINT
1130  GOTO 1059
1140  PRINT : PRINT "LISTING ENDED": PRINT  CHR$ (12): PR# 0
1150  PRINT "1 TO LIST AGAIN"
1152  INPUT "2 TO RUN PROGRAM AGAIN";G
1153  IF G = 1 THEN  GOTO 1050
1170  GOTO 8
3000  PRINT : PRINT "1 FOR SINGLE RECORD"
3005  PRINT "2 FOR OVERLAYS "
3006  INPUT "3 FOR STAT OPTIONS ";G
3007  IF G = 2 THEN  GOTO 6000
3008  IF G = 3 THEN  GOTO 3500
3012  INPUT "FILE NUMBER (0-59): ";Z
3013  PRINT : PRINT "ACCESSING FILE B";Z: GOSUB 9500
3040  IF ER = 1 THEN  PRINT "FILE EMPTY":ER = 0: GOTO 3012
3090  PRINT : PRINT "DATA RETRIEVED": PRINT
3092  PRINT "1 FOR TABLE LISTING,
3093  INPUT "2 FOR GRAPH.";G
3094  IF G = 1 THEN  GOTO 1050
3100  HGR2 : HCOLOR= 7
3110 XM = 0: GOSUB 7000
3129 G = 0: GOSUB 8000
3200  INPUT A$: IF A$ = "P" THEN  GOSUB 9000
3210  CALL 62450: HOME : TEXT
3220  INPUT "PRESS RETURN FOR CYCLE FREQUENCY ";A$: HGR2
3240 XM = 0: GOSUB 7000
3250  FOR I = 0 TO (60 * MINS) - 1
3260 FR =  PEEK (DSTART + 2 + (3 * I))
3280  HCOLOR= 7: HPLOT I + 10,128 TO I + 10,128 - (6.4 * FR)
3290  NEXT I: INPUT A$: IF A$ = "P" THEN  GOSUB 9000
3310  HOME : TEXT : CALL 62450: GOTO 1150
3500  REM  *STAT ROUTINE*
3505  HOME
3510  PRINT : PRINT "(1) SHOW TRIAL AND MEAN, SD"
3530  HGR2 : HCOLOR= 7:XM = 0: GOSUB 7000
3540  GOSUB 8000
3550  PRINT D$;"BLOAD BSTAT,A25561"
3555  FOR I = 0 TO (60 * MINS) - 1
3560 N =  PEEK (SSTART + (3 * I)): IF N = 0 THEN  GOTO 3610
3565 XSUM =  PEEK (SSTART + 1 + (3 * I))
3570 X2SUM =  PEEK (SSTART + 2 + (3 * I))
3580 SDEV = 10 * ( SQR ((N * X2SUM) - (XSUM ^ 2))) / N
```

```
3585 S1 = XBAR + SDEV: IF S1 > 100 THEN S1 = 100
3590 S2 = XBAR - SDEV: IF S2 < 0 THEN S2 = 0
3595  HPLOT I + 10,128 - (1.28 * S1)
3600  HPLOT I + 10,128 - (1.28 * S2)
3605  NEXT I
3610  INPUT A$:X =  FRE (0): IF A$ = "P" THEN  GOSUB 9000
3615  CALL 62450: HOME : TEXT
3621  PRINT "   (LAST FILE ADDED= "; PEEK (25561);"  )"
3622  PRINT "   (THIS FILE IS #";Z;")"
3640  GOTO 3000
6000  PRINT : PRINT "VARIABLES: 1 = OVERALL %"
6020  PRINT : PRINT "           2 = INSTANTANEOUS %"
6025  PRINT : INPUT "           3 = CYCLE FREQUENCY ";G
6040  PRINT : INPUT "1ST FILE: ";TR
6060  PRINT : INPUT "2ND FILE: ";UR
6070  PRINT : PRINT "1 FOR ONLY THESE TWO:"
6071  INPUT "2 FOR ALL FILES IN BETWEEN.";ZR
6075  IF ZR = 2 THEN  PRINT : PRINT "   FILES ";TR;" THROUGH ";UR: GOTO 61
00
6080  PRINT : PRINT "ACCESSING VARIABLE ";G
6085  PRINT "       FILES ";TR;" & ";UR
6100 Z = TR: GOSUB 9500
6110  IF ER = 1 THEN  PRINT "FILE EMPTY":ER = 0: GOTO 6040
6150  HGR2 : CALL 62450
6155 XM = 0: GOSUB 7000: GOSUB 8000
6160  IF ZR = 2 THEN Z = Z + 1: GOSUB 9500: GOTO 6190
6170 Z = UR: GOSUB 9500
6190  IF ER = 1 THEN  TEXT : PRINT "FILE EMPTY":ER = 0: GOTO 6040
6230  GOSUB 8000
6235  IF Z < UR THEN  GOTO 6160
6240  INPUT A$: IF A$ = "P" THEN  GOSUB 9000
6245  CALL 62450: HOME : TEXT
6260  PRINT "1 FOR MORE OVERLAYS,"
6270  INPUT "2 TO EXIT. ";G
6280  IF G = 1 THEN  GOTO 6000
6290  GOTO 8
7000  HCOLOR= 7
7010  HPLOT 5,0 TO 5,131 TO 270,131
7020  FOR I = 0 TO 10
7030 J = 3: IF I = 0 OR I = 5 OR I = 10 THEN J = 0
7040  HPLOT J,12.8 * I TO 5,12.8 * I
7050  NEXT I
7055  IF XM = 1 THEN  GOTO 7070
7060  FOR I = 0 TO 3
7061  FOR J = 0 TO 5:K = 2
7062  IF J = 0 THEN K = 7
7063  IF J = 3 THEN K = 4
7064 QX = (I * 60) + (J * 10) + 10
7065  HPLOT QX,131 TO QX,131 + K
7066  NEXT J
7067  NEXT I
7070  RETURN
8000  FOR I = 0 TO (60 * MINS) - 1
8001  IF G = 1 THEN  GOTO 8010
8002  IF G = 2 THEN  GOTO 8020
8003  IF G = 3 THEN  GOTO 8030
8010  IF G = 0 THEN  HCOLOR= 7
8012 SY = 128 - (1.28 *  PEEK (DSTART + 1 + (3 * I)))
8013  IF SY < 0 THEN SY = 0
8014  HPLOT I + 10,SY
8015  IF G > 0 THEN  GOTO 8050
8020  IF G = 0 THEN  HCOLOR= 7
8021 PY = 128 - (1.28 *  PEEK (DSTART + (3 * I)))
8022  IF PY < 0 THEN PY = 0
8023  HPLOT I + 10,PY
8024  IF G > 0 THEN  GOTO 8050
8030  IF G = 0 THEN  HCOLOR= 7
8031 FR =  PEEK (DSTART + 2 + (3 * I))
8033  IF G = 0 THEN  HPLOT I + 10,128 TO I + 10,128 - (FR): GOTO 8050
8035  HPLOT I + 10,128 - (6.4 * FR)
8050 G = G
8095  NEXT I
8099  RETURN
9000  REM  SUBRT TO LINK PRINTER PROGRAM
9005  TEXT : PRINT "STORING . . ."
9010  PRINT D$;"BSAVE HRES,A16384,L8191,D1"
9012  PRINT : PRINT "LOADING GRAPHICS PROGRAM...": PRINT
9015  PRINT D$;"RUN PARA PRINT"
9020  RETURN
9500  REM  SUBRT TO RETRIEVE A FILE
```

```
9501  REM  NEEDS "Z" FROM MAIN PROGRAM
9505  IF  PEEK (WSTART + Z) = 0 THEN ER = 1: GOTO 9580
9510  PRINT D$;"BLOAD B";Z;",A";DSTART - 10
9511 SBNUM =  PEEK (24576)
9512 CDN =  PEEK (24577)
9513 TL =  PEEK (24578)
9514 DAY =  PEEK (24579)
9515 MTH =  PEEK (24580)
9516 YEAR =  PEEK (24581)
9517 HOUR =  PEEK (24582)
9518 MNTS =  PEEK (24583)
9519 MINS = ( PEEK (24584)) / 10
9520 MVOLTS =  PEEK (24585)
9580  RETURN
9800  REM  ID DISPLAY SUBROUTINE
9801  PRINT : PRINT "I TO INSPECT": PRINT : INPUT "P TO PRINT: ";A$
9802 CP = 0: IF A$ = "P" THEN CP = 1
9803  IF CP = 0 THEN  GOTO 9810
9804  PR# 1: PRINT  CHR$ (9);"80N": PRINT  CHR$ (30): PRINT  CHR$ (01)
9810  PRINT : PRINT "S# ";SBNUM;" / CONDITION ";CDN;" / TRIAL ";TL
9815  PRINT
9820  IF MNTS > 9 THEN  PRINT "AT ";HOUR;":";MNTS;"  ON  ";MTH;"/";DAY;"/"
     ;YEAR: GOTO 9860
9830  PRINT "AT ";HOUR;":0";MNTS;"  ON  ";MTH;"/";DAY;"/";YEAR
9860  PRINT
9866  PRINT "LENGTH: ";MINS;" MINUTES"; SPC( 3);"LEVEL: ";MVOLTS;" MICROVO
     LTS"
9867  PRINT "----------------------------------------"
9868  IF CP = 1 THEN  PRINT : PRINT  CHR$ (02): GOTO 9880
9870  INPUT A$
9880  RETURN
```

```
]

?SYNTAX ERROR
]PROGRAM TO LIST SUMMARIZED DATA

?SYNTAX ERROR
]LIST

1 D$ =  CHR$ (4)
4  HIMEM: 16384:USTART = 13000
5  DEF  FN C(Q) =  PEEK (WLOC + Q)
6 MAR = 5: REM  MARGIN SET AT 5
8  CALL 62450: TEXT : HOME :X =  FRE (0): GOTO 3000
9 )) / 100
3000  PRINT : PRINT "LISTINGS OF SUMMARIZED DATA BY SUBJEXT:"
3001  INPUT "FIRST SUBJECT #:";B: IF (B < 1) OR (B > 27) THEN  GOTO 3001
3002  INPUT "FINAL SUBJECT #:";C: IF (C < B) OR (C > 27) THEN  GOTO 3002
3003  GOTO 9900
9900  REM  FILE HEADER PRINT ROUTINE
9901  PRINT D$;"PR#1": PRINT  CHR$ (9);"80N": PRINT  CHR$ (30): PRINT  CHR$
     (02)
9902  FOR I = B TO C
9903  PRINT D$;"BLOAD S";I;",A";USTART;",D2"
9904  FOR K = 1 TO 3
9905  PRINT  CHR$ (11): REM  VERTICAL TAB
9906  NEXT K
9907  PRINT  SPC( MAR);"SUBJECT #";I: PRINT
9908  PRINT  SPC( MAR);"FILE #   CONDITION   TRIAL#   LENGTH   DATE    TIM
     E   LEVEL    % ALPHA    FREQ."
9909  PRINT
9920  FOR J = 0 TO 31
9922 WLOC = USTART + (10 * J)
9924  IF  FN C(0) = 0 THEN  GOTO 9936
9925  PRINT
9926  IF  FN C(6) > 9 THEN  GOTO 9934
9928  PRINT  SPC( MAR + 1);J; SPC( 10); FN C(0); SPC( 8); FN C(1); SPC( 8)
     ;( FN C(2)) / 10; SPC( 4); FN C(3);"/"; FN C(4);"/'80"; SPC( 3); FN C
     (5);":0"; FN C(6); SPC( 5); FN C(7); SPC( 8); FN C(8); SPC( 7);( FN C
     (9)) / 100
9930  GOTO 9935
9934  PRINT  SPC( MAR + 1);J; SPC( 10); FN C(0); SPC( 8); FN C(1); SPC( 8)
     ;( FN C(2)) / 10; SPC( 4); FN C(3);"/"; FN C(4);"/'80"; SPC( 3); FN C
     (5);":"; FN C(6); SPC( 5); FN C(7); SPC( 8); FN C(8); SPC( 7);( FN C(
     9)) / 100
9935  NEXT J
9936  PRINT  CHR$ (12)
9938  NEXT I
9940  PRINT D$;"PR#0"
9942  PRINT  CHR$ (7); CHR$ (7)
9944  PRINT "LISTING COMPLETED"
9946  INPUT "M FOR MORE, Q TO QUIT";A$
9948  IF A$ = "M" THEN  GOTO 8
9950  END
```

```
]

?SYNTAX ERROR
]PRINT PROGRAM TO PERFORM REGRESSION & CORRELATION ON SUMMARY DATA
0
?SYNTAX ERROR
]LIST

1 D$ =  CHR$ (4)
4  HIMEM: 16384:USTART = 13000
5  CALL 62450: PRINT "LOADING CHARACTERS"
6  PRINT  CHR$ (4);"BLOAD A/N,A8192": POKE 232,0: POKE 233,32
8  CALL 62450: TEXT : HOME :X =  FRE (0): GOTO 3000
3000  PRINT "REGRESSION & CORRELATION:": INPUT "SUBJECT #:";G
3001  GOTO 9900
7000  HCOLOR= 7: REM   AXES SUBRT
7002  HPLOT 75,0 TO 75,131 TO 259,131
7004  FOR I = 0 TO 10
7006 J = 3: IF I = 0 OR I = 5 OR I = 10 THEN J = 0
7008  HPLOT J + 70,12.8 * I TO 75,12.8 * I
7010  NEXT I
7012  FOR I = 0 TO 12
7014 J = 2: IF I = 0 OR I = 5 OR I = 10 THEN J = 5
7016 QX = (14.976 * I) + 78
7018  HPLOT QX,131 TO QX,131 + J
7019  NEXT I
7020  SCALE= 1: ROT= 0
7022  DRAW 18 AT 60,131: DRAW 16 AT 55,67: DRAW 23 AT 60,67
7024  DRAW 19 AT 48,7: DRAW 16 AT 55,7: DRAW 18 AT 60,7
7026  DRAW 18 AT 76,146: DRAW 16 AT 149,146: DRAW 23 AT 154,146
7028  DRAW 19 AT 220,146: DRAW 16 AT 227,146: DRAW 18 AT 232,146
7030  RETURN
9600  REM  CONVERSION SUBROUTINE
9602  IF  PEEK (WLOC) = 0 THEN ER = 1: GOTO 9610
9604 FRSUM = ( PEEK (WLOC + 9)) / 100
9606 PER = ( PEEK (WLOC + 8)) / 100
9610  RETURN
9900  REM  CALC (REG/CORR) ROUTINE
9901  INPUT "LARGE OR SMALL GRAPH?";L$
9902  HGR2 : GOSUB 7000
9903 XS = 0:XQ = 0:YS = 0:YQ = 0:XY = 0:N = 0: SCALE= 1: ROT= 0: IF L$ = "
     S" THEN  SCALE= 2
9904  PRINT D$;"BLOAD S";G;",A";USTART;",D2":Z = 0
9905  FOR I = 0 TO 31
9906 WLOC = USTART + (10 * I)
9907  GOSUB 9600: IF ER = 1 THEN  GOTO 9921
9908 XS = XS + FRSUM:YS = YS + PER
9909 XY = XY + (FRSUM * PER)
9911 XQ = XQ + (FRSUM ↑ 2):YQ = YQ + (PER ↑ 2)
9913 N = N + 1
9915 YP = 128 - (1.28 * (100 * PER))
9916 XP = 78 + (149.76 * FRSUM)
9917  DRAW 66 AT XP,YP
9920  NEXT I
9921 BN = (N * XY) - (XS * YS):BD = (N * XQ) - (XS ↑ 2):ER = 0
9923 BF = BN / BD
9925 AF = (YS / N) - (BF * (XS / N))
9927 RD =  SQR ((N * XQ) - (XS ↑ 2)) *  SQR ((N * YQ) - (YS ↑ 2))
9929 RF = BN / RD:TF = (RF *  SQR (N - 2)) /  SQR (1 - RF ↑ 2)
9930 X1 = 0:Y1 = AF
9931  IF AF <  - .15 THEN X1 = ( - .15 - AF) / BF:Y1 =  - .15
9932  IF AF > 1.0 THEN X1 = (1 - AF) / BF:Y1 = 1
9933 X2 = 1.2:Y2 = (BF * 1.2) + AF:PY = Y2
9934  IF PY > 1.0 THEN X2 = (1 - AF) / BF:Y2 = 1
9935  IF PY <  - .15 THEN X2 = ( - .15 - AF) / BF:Y2 =  - .15
9936  HPLOT (149.76 * X1) + 78,128 - (1.28 * (100 * Y1)) TO (149.76 * X2) +
     78,128 - (1.28 * (100 * Y2))
9937  PRINT  CHR$ (7); CHR$ (7): INPUT " ";A$
9939  TEXT : HOME : PRINT "STORING . . ."
9940  PRINT D$;"BSAVE HRES,A16384,L8191,D1": PRINT "STORED"
9941  PRINT D$;"PR#1": PRINT  CHR$ (9);"80N": PRINT  CHR$ (02): PRINT  CHR$
     (30)
9942  PRINT  CHR$ (11): PRINT  CHR$ (11): PRINT  CHR$ (11): PRINT  CHR$ (1
     1): PRINT  SPC( 22);"SUBJECT #";G: PRINT
9943  PRINT : PRINT  SPC( 24);"X = FREQUENCY OF STATE CHANGE (FULL CYCLE I
     N HZ)": PRINT
9944  PRINT  SPC( 24);"Y = PROPORTION OF TIME IN ALPHA": PRINT
9946  IF AF < 0 GOTO 9948
9947  PRINT  SPC( 26);"REGRESSION:   Y = ";BF;"X + ";AF: GOTO 9949
```

```
9948  PRINT  SPC( 26);"REGRESSION:   Y = ";BF;"X ";AF
9949  PRINT : PRINT  SPC( 26)"CORRELATION:  R = ";RF
9950  PRINT : PRINT  SPC( 40);"T = ";TF;"     DF = ";N - 2: PRINT : PRINT  SPC(
     40);"N = ";N
9951  PRINT : PRINT : PRINT D$;"PR#0"
9953  PRINT "LOADING GRAPHICS PROGRAM..."
9955  PRINT D$;"RUN PARA PRINT 2,D1"
9957  END
```

```
]PR#0
]

?SYNTAX ERROR
]PRINT 1-WAY ANOVA, WITHIN SUBJECT
1              0

]LIST

1 D$ =  CHR$ (4)
3  DEF  FN ASN(X) =  ATN (X /  SQR ( - X * X + 1))
5  DIM SS(4): DIM MS(4): DIM ME(2): DIM DF%(4): DIM F(2)
10  DIM MAD(4,16): DIM BUF(4,16)
12  DIM ST(16): DIM CT(4)
14  HOME
15  PRINT "REPEATED MEASURES ANOVA:"
17  PRINT "ONE-WAY, WITHIN-SUBJECT"
20  PRINT : INPUT "# OF LEVELS OF VARIABLE: ";V1
22  INPUT "VARIABLE NAME: ";AN$
28  IF (V1 > 4) THEN  PRINT "TOO MANY VARIABLE LEVELS:  MUST BE <5": GOTO
    20
29  INPUT "# OF SUBJECTS: ";SN
30  INPUT "DEPENDENT VARIABLE NAME: ";G$
31  PRINT : PRINT "INPUT DATA"
32  FOR I = 1 TO V1
35  HOME
36  FOR K = 1 TO SN
38  PRINT "A";I;", S";K
40  INPUT "VALUE = ";BUF(I,K)
42  NEXT K
46  NEXT I: HOME
48  PRINT "DATA MATRIX COMPLETE": GOSUB 400
50  PRINT "WORKING ON ANALYSIS"
52  FOR I = 1 TO 4
54 SS(I) = 0:MS(I) = 0:CT(I) = 0
56  NEXT I
57 AQ = 0:TQ = 0:SQ = 0:SA = 0:SB = 0:AS = 0:TT = 0:XQ = 0
58 TS = 0
60  FOR I = 1 TO 16
61 ST(I) = 0
62  NEXT I
67  FOR I = 1 TO V1
69  FOR K = 1 TO SN
70 TT = TT + MAD(I,K)
71 CT(I) = CT(I) + MAD(I,K):ST(K) = ST(K) + MAD(I,K)
74  NEXT K: NEXT I
80 DF%(1) = V1 - 1:DF%(2) = SN - 1
81 DF%(3) = DF%(1) * DF%(2):DF%(4) = (V1 * SN) - 1
82 TQ = TT ↑ 2
84  FOR I = 1 TO V1
85  FOR K = 1 TO SN
86 XQ = XQ + MAD(I,K) ↑ 2
88  NEXT K: NEXT I
89  FOR I = 1 TO V1
90 AQ = AQ + CT(I) ↑ 2
91  NEXT I
92  FOR I = 1 TO SN
93 SQ = SQ + ST(I) ↑ 2
94  NEXT I
96 SA = (AQ / SN)
98 SB = (SQ / V1)
100 AS = XQ
102 TS = (TT ↑ 2) / (V1 * SN)
104 SS(1) = SA - TS
106 SS(2) = SB - TS
108 SS(3) = AS - SA - SB + TS
110 SS(4) = AS - TS
130  FOR I = 1 TO 3
132 MS(I) = SS(I) / DF%(I)
134  NEXT I
140 F(1) = MS(1) / MS(3):F(2) = MS(2) / MS(3)
144 F% = 100 * F(1):F(1) = F% / 100:F% = 100 * F(2):F(2) = F% / 100
146  HOME : PRINT "ANOVA SUMMARY TABLE:  ";AN$;" BY SUBJECTS"
148  PRINT "--------------------------------------"
150  PRINT "SOURCE"; SPC( 2);"S.S."; SPC( 6);"D.F."; SPC( 4);"M.S."; SPC(
     7);"F"
152  PRINT "--------------------------------------"
154  DATA     "  A  ","  S  "," AXS "
156  RESTORE
160  FOR I = 1 TO 3
```

```
162  READ Q$: IF ((I = 1) OR (I = 2)) THEN  GOTO 166
164  PRINT : PRINT Q$; SPC( 1);SS(I); TAB( 19);DF%(I); TAB( 23);MS(I): GOTO
     168
166  PRINT : PRINT Q$; SPC( 1);SS(I); TAB( 19);DF%(I); TAB( 23);MS(I); TAB(
     35);F(I)
168  NEXT I
169  PRINT "----------------------------------------"
170  PRINT "TOTAL"; SPC( 1);SS(4); SPC( 2);DF%(4)
172  INPUT Z$: RESTORE
174  INPUT "HARD COPY? (Y/N) ";Z$
176  IF Z$ = "Y" THEN  PRINT D$;"PR#1": PRINT  C[illegible] (9);"80N": PRINT  CHR$
     (30): PRINT  CHR$ (02): GOTO 180
177  HOME : INPUT "C TO CONTINUE, N FOR NEW DATA  A$
178  IF A$ = "C" THEN  GOTO 48
179  HOME : GOTO 15
180  PRINT "ANOVA SUMMARY TABLE:  ";AN$;" BY SUBJECTS"
182  PRINT "----------------------------------------"
184  PRINT "SOURCE"; SPC( 2);"S.S."; SPC( 6);"D.F."; SPC( 4);"M.S."; SPC(
     7);"F"
186  PRINT "----------------------------------------"
188  FOR I = 1 TO 3
190  READ Q$: IF ((I = 1) OR (I = 2)) THEN  GOTO 194
192  PRINT : PRINT Q$; SPC( 1);SS(I); SPC( 3);DF%(I); SPC( 2);MS(I): GOTO
     195
194  PRINT : PRINT Q$; SPC( 1);SS(I); SPC( 3);DF%(I); SPC( 2);MS(I); SPC(
     2);F(I)
195  NEXT I
196  PRINT "----------------------------------------"
197  PRINT "TOTAL"; SPC( 1);SS(4); SPC( 2);DF%(4): GOSUB 300
198  PRINT  CHR$ (12): PRINT D$;"PR#0": GOTO 172
300  REM  PRINT MEANS
302  PRINT : PRINT : PRINT "CELL MEANS:": PRINT
304  FOR I = 1 TO V1
308  PRINT "A";I;" = ";CT(I) / SN
309  PRINT
310  NEXT I
312  PRINT
314  IF TFRM > 4 THEN A$ = "1/"
315  IF TFRM = 4 THEN A$ = "LOG"
316  IF TFRM = 3 THEN A$ = "ARCSINE"
317  IF TFRM = 2 THEN A$ = "SQUARE ROOT"
318  PRINT "DEPENDENT VARIABLE = ";G$
319  IF TFRM > 1 THEN  PRINT "TRANSFORMED BY ";A$;"(X+";CN;")"
320  RETURN
400  REM  PICK TRANSFORMATION
401 TFRM = 0: PRINT "TRANSFORMATION:": PRINT
402  PRINT "1 = NONE"
404  PRINT "2 = SQUARE ROOT"
406  PRINT "3 = ARCSINE"
408  PRINT "4 = LOG(X)"
409  INPUT "5 = 1/X";TFRM
410 CN = 0
412  PRINT : INPUT "ADD/SUBTRACT CONSTANT: ";CN
413  PRINT "TRANSFORMING"
414  FOR I = 1 TO V1
418  FOR K = 1 TO SN
419 W = BUF(I,K)
420  IF TFRM > 4 THEN T = 1 / (W + CN)
422  IF TFRM = 4 THEN T =  LOG (W + CN)
424  IF TFRM = 3 THEN T =  FN ASN(W + CN)
426  IF TFRM = 2 THEN T =  SQR (W + CN)
428  IF TFRM < 2 THEN T = W
430 MAD(I,K) = T
432  NEXT K: NEXT I
434  RETURN
```

```
]PR#0
]

?SYNTAX ERROR
]PRINT 2-WAY ANOVA, WITHIN-SUBJECT
2            0

]LIST

1 D$ =  CHR$ (4)
3  DEF  FN ASN(X) =  ATN (X /  SQR ( - X * X + 1))
5  DIM SS(8): DIM MS(8): DIM ME(4,4): DIM DF%(8)
10  DIM MAD(4,4,16): DIM SA(4,16): DIM SB(4,16): DIM BUF(4,4,16)
14  HOME
15  PRINT "REPEATED MEASURES ANOVA:"
17  PRINT "TWO VARIABLES, WITHIN-SUBJECT"
20  PRINT : INPUT "# OF LEVELS, VARIABLE 1: ";V1
22  INPUT "VARIABLE NAME: ";AN$
24  PRINT : INPUT "# OF LEVELS, VARIABLE 2: ";V2
26  INPUT "VARIABLE NAME: ";BN$
28  IF (V1 > 4) OR (V2 > 4) THEN  PRINT "TOO MANY VARIABLE LEVELS: MUST BE
     <5": GOTO 20
29  INPUT "# OF SUBJECTS: ";SN
30  INPUT "DEPENDENT VARIABLE: ";G$
31  PRINT : PRINT "INPUT DATA"
32  FOR I = 1 TO V1
34  FOR J = 1 TO V2
35  HOME
36  FOR K = 1 TO SN
38  PRINT "A";I;", B";J;", S";K
39  REM  GOTO 41 SOMETIMES
40  INPUT "VALUE = ";BUF(I,J,K)
41  REM  READ MAD(I,J,K) SOMETIMES...
42  NEXT K
44  NEXT J
46  NEXT I: HOME
48  PRINT "DATA MATRIX COMPLETE": GOSUB 400
50  PRINT "WORKING ON ANALYSIS"
52  FOR I = 1 TO 8
54 SS(I) = 0:MS(I) = 0
56  NEXT I
57  FOR I = 1 TO 4
58  FOR J = 1 TO 12
59 SA(I,J) = 0:SB(I,J) = 0
60  NEXT J: NEXT I
61  FOR I = 1 TO 4
62  FOR J = 1 TO 4
63 ME(I,J) = 0
64  NEXT J: NEXT I
65 T = 0:A = 0:S = 0:AS = 0:B = 0:BS = 0:AB = 0:AXBXS = 0
67  FOR I = 1 TO V1
68  FOR J = 1 TO V2
69  FOR K = 1 TO SN
70 T = T + MAD(I,J,K):AXBXS = AXBXS + (MAD(I,J,K)) ^ 2
71 SA(I,K) = SA(I,K) + MAD(I,J,K)
72 SB(J,K) = SB(J,K) + MAD(I,J,K)
73 ME(I,J) = ME(I,J) + MAD(I,J,K)
74  NEXT K: NEXT J: NEXT I
75  REM  GOSUB 200 SOMETIMES...
76 T = (T ^ 2) / (V1 * V2 * SN)
80  FOR I = 1 TO V1
81 K = 0
82  FOR J = 1 TO V2
84 K = K + ME(I,J)
85 AB = AB + (ME(I,J)) ^ 2
86  NEXT J:A = A + K ^ 2
88  NEXT I:A = A / (V2 * SN):AB = AB / SN
90 K = 0
92  FOR J = 1 TO V2
93 K = 0
94  FOR I = 1 TO V1
96 K = K + ME(I,J)
98  NEXT I:B = B + K ^ 2
99  NEXT J:B = B / (V1 * SN)
100  FOR I = 1 TO SN
101 K = 0
102  FOR J = 1 TO V1
104 K = K + SA(J,I):AS = AS + (SA(J,I)) ^ 2
106  NEXT J:S = S + K ^ 2:K = 0
108  FOR J = 1 TO V2
```

```
110 BS = BS + (SB(J,I)) ↑ 2
112  NEXT J
114  NEXT I:AS = AS / V2:BS = BS / V1:S = S / (V1 * V2)
115 SS(1) = A - T:SS(2) = S - T:SS(3) = AS - A - S + T
117 SS(4) = B - T:SS(5) = BS - B - S + T:SS(6) = AB - A - B + T
119 SS(7) = AXBXS - AB - AS - BS + A + B + S - T:SS(8) = AXBXS - T
120 DF%(1) = V1 - 1:DF%(2) = SN - 1:DF%(3) = (V1 - 1) * (SN - 1)
122 DF%(4) = V2 - 1:DF%(5) = (V2 - 1) * (SN - 1):DF%(6) = (V1 - 1) * (V2 -
    1)
124 DF%(7) = (V1 - 1) * (V2 - 1) * (SN - 1):DF%(8) = (V1 * V2 * SN) - 1
130  FOR I = 1 TO 7
132 MS(I) = SS(I) / DF%(I)
134  NEXT I
140 F1 = MS(1) / MS(3):F2 = MS(4) / MS(5)
142 F3 = MS(6) / MS(7)
144 F% = 100 * F1:F1 = F% / 100:F% = 100 * F2:F2 = F% / 100:F% = 100 * F3:
    F3 = F% / 100
145 F(1) = F1:F(4) = F2:F(6) = F3
146  HOME : PRINT "ANOVA SUMMARY TABLE:  ";AN$;" BY ";BN$
148  PRINT "----------------------------------------"
150  PRINT "SOURCE"; SPC( 2);"S.S."; SPC( 6);"D.F."; SPC( 4);"M.S."; SPC(
     7);"F"
152  PRINT "----------------------------------------"
154  DATA "  A  "," S  "," AXS "," B  "," BXS "," AXB ","AXBXS"
156  RESTORE
160  FOR I = 1 TO 7
162  READ Q$: IF ((I = 1) OR (I = 4) OR (I = 6)) THEN  GOTO 166
164  PRINT : PRINT Q$; SPC( 1);SS(I); TAB( 19);DF%(I); TAB( 23);MS(I): GOTO
     168
166  PRINT : PRINT Q$; SPC( 1);SS(I); TAB( 19);DF%(I); TAB( 23);MS(I); TAB(
     35);F(I)
168  NEXT I
169  PRINT "----------------------------------------"
170  PRINT "TOTAL"; SPC( 1);SS(8); SPC( 2);DF%(8)
172  INPUT Z$: RESTORE
174  INPUT "HARD COPY? (Y/N) ";Z$
176  IF Z$ = "Y" THEN  PRINT D$;"PR#1": PRINT  CHR$ (9);"80N": PRINT  CHR$
     (30): PRINT  CHR$ (02): GOTO 180
177  HOME : INPUT "C TO CONTINUE, N FOR NEW DATA";A$
178  IF A$ = "C" THEN  GOTO 48
179  HOME : GOTO 15
180  PRINT "ANOVA SUMMARY TABLE:  ";AN$;" BY ";BN$
182  PRINT "----------------------------------------"
184  PRINT "SOURCE"; SPC( 2);"S.S."; SPC( 6);"D.F."; SPC( 4);"M.S."; SPC(
     7);"F"
186  PRINT "----------------------------------------"
188  FOR I = 1 TO 7
190  READ Q$: IF ((I = 1) OR (I = 4) OR (I = 6)) THEN  GOTO 194
192  PRINT : PRINT Q$; SPC( 1);SS(I); SPC( 3);DF%(I); SPC( 2);MS(I): GOTO
     195
194  PRINT : PRINT Q$; SPC( 1);SS(I); SPC( 3);DF%(I); SPC( 2);MS(I); SPC(
     2);F(I)
195  NEXT I
196  PRINT "----------------------------------------"
197  PRINT "TOTAL"; SPC( 1);SS(8); SPC( 2);DF%(8): GOSUB 300
198  PRINT  CHR$ (12): PRINT D$;"PR#0": GOTO 172
200  HOME
202  PRINT "ABS MATRIX"
206  FOR I = 1 TO V1
208  FOR J = 1 TO V2
210  FOR K = 1 TO SN
212  PRINT K; SPC( 4);MAD(I,J,K)
214  NEXT K: INPUT Z$: NEXT J: NEXT I
216  INPUT Z$
220  HOME : PRINT "AS MATRIX"
222  FOR I = 1 TO SN
224  PRINT I; SPC( 4);SA(1,I); SPC( 4);SA(2,I)
226  NEXT I: INPUT Z$
230  HOME : PRINT "BS MATRIX"
232  FOR I = 1 TO SN
234  PRINT I; SPC( 3);SB(1,I); SPC( 3);SB(2,I); SPC( 3);SB(3,I); SPC( 3);S
     B(4,I)
236  NEXT I: INPUT Z$
240  HOME : PRINT "AB MATRIX"
242  FOR I = 1 TO V1
244  PRINT I; SPC( 3);ME(I,1); SPC( 3);ME(I,2); SPC( 3);ME(I,3); SPC( 3);M
     E(I,4)
246  NEXT I: INPUT Z$
248  RETURN
300  REM  PRINT MEANS
```

```
302  PRINT : PRINT : PRINT "CELL MEANS:": PRINT
304  FOR I = 1 TO V1
306  FOR J = 1 TO V2
308  PRINT "A";I;" B";J;" = ";ME(I,J) / SN
309  PRINT
310  NEXT J: NEXT I
312  PRINT
314  IF TFRM > 4 THEN A$ = "1/"
315  IF TFRM = 4 THEN A$ = "LOG"
316  IF TFRM = 3 THEN A$ = "ARCSINE"
317  IF TFRM = 2 THEN A$ = "SQUARE ROOT"
318  PRINT "DEPENDENT VARIABLE = ";G$
319  IF TFRM > 1 THEN  PRINT "TRANSFORMED BY ";A$;"(X+";CN;")"
320  RETURN
400  REM  PICK TRANSFORMATION
401 TFRM = 0: PRINT "TRANSFORMATION:": PRINT
402  PRINT "1 = NONE"
404  PRINT "2 = SQUARE ROOT"
406  PRINT "3 = ARCSINE"
408  PRINT "4 = LOG(X)"
409  INPUT "5 = 1/X";TFRM
410 CN = 0
412  PRINT : INPUT "ADD/SUBTRACT CONSTANT: ";CN
413  PRINT "TRANSFORMING"
414  FOR I = 1 TO V1
416  FOR J = 1 TO V2
418  FOR K = 1 TO SN
419 W = BUF(I,J,K)
420  IF TFRM > 4 THEN T = 1 / (W + CN)
422  IF TFRM = 4 THEN T =  LOG (W + CN)
424  IF TFRM = 3 THEN T =  FN ASN(W + CN)
426  IF TFRM = 2 THEN T =  SQR (W + CN)
428  IF TFRM < 2 THEN T = W
430 MAD(I,J,K) = T
432  NEXT K: NEXT J: NEXT I
434  RETURN
```

# APPENDIX C:

# ANOVA SUMMARY TABLES

Table . Summary of analysis of variance of % alpha categorical by training exposure.

ANOVA SUMMARY TABLE: TRAINING BY SUBJECTS

| SOURCE | S.S. | D.F. | M.S. | F |
|---|---|---|---|---|
| A | 561.124992 | 1 | 561.124992 | 3.72 |
| S | 11228 | 15 | 748.533332 | 4.96 |
| AXS | 2260.87501 | 15 | 150.725001 | |
| TOTAL | 14050 | 31 | | |

CELL MEANS:

A1 = 23.8125

A2 = 32.1875

DEPENDENT VARIABLE = % ALPHA

Table 2. Summary of analysis of variance of log cycle frequency categorical by training exposure.

ANOVA SUMMARY TABLE: TRAINING BY SUBJECTS

| SOURCE | S.S. | D.F. | M.S. | F |
|---|---|---|---|---|
| A | .193226069 | 1 | .193226069 | 1.37 |
| S | 34.329386 | 15 | 2.28862573 | 16.23 |
| AXS | 2.11394075 | 15 | .140929383 | |
| TOTAL | 36.6365528 | 31 | | |

CELL MEANS:

A1 = -.956967284

A2 = -1.11238046

DEPENDENT VARIABLE = CYCLE FREQUENCY
TRANSFORMED BY LOG( X+0 )

**Table 3. Summary of analysis of variance of % alpha categorical by feedback conditions and eye condition.**

ANOVA SUMMARY TABLE: FEEDBACK BY EYES

| SOURCE | S.S. | D.F. | M.S. | F |
|---|---|---|---|---|
| A | 504.099991 | 1 | 504.099991 | 6.47 |
| S | 5773.09998 | 9 | 641.455553 | |
| AXS | 702.400009 | 9 | 78.0444455 | |
| B | 3534.39999 | 1 | 3534.39999 | 21.6 |
| BXS | 1472.10001 | 9 | 163.566667 | |
| AXB | 448.900009 | 1 | 448.900009 | 8.33 |
| AXBXS | 484.599991 | 9 | 53.8444434 | |
| TOTAL | 12919.6 | 39 | | |

CELL MEANS:

A1 B1 = 45.7

A1 B2 = 20.2

A2 B1 = 31.9

A2 B2 = 19.8

DEPENDENT VARIABLE = RAW % ALPHA

Table 4. Summary of analysis of variance of baseline-scaled % alpha categorical by feedback condition and eye condition.

ANOVA SUMMARY TABLE: FEEBACK BY EYES

| SOURCE | S.S. | D.F. | M.S. | F |
|---|---|---|---|---|
| A | 577.600001 | 1 | 577.600001 | 7.28 |
| S | 3528.1 | 9 | 392.011111 | |
| AXS | 713.900003 | 9 | 79.3222226 | |
| B | 32.4000001 | 1 | 32.4000001 | .17 |
| BXS | 1621.1 | 9 | 180.172222 | |
| AXB | 384.399999 | 1 | 384.399999 | 7.79 |
| AXBXS | 444.100001 | 9 | 49.3444445 | |
| TOTAL | 7301.6 | 39 | | |

CELL MEANS:

A1 B1 = 9.4

A1 B2 = 5

A2 B1 = -4.4

A2 B2 = 3.6

DEPENDENT VARIABLE = BASELINE-SCALED % ALPHA

Table 5. Summary of analysis of variance of log baseline-scaled % alpha categorical by feedback condition and eye condition.

ANOVA SUMMARY TABLE: FEEDBACK BY EYES

| SOURCE | S.S. | D.F. | M.S. | F |
|---|---|---|---|---|
| A | 1.13943768 | 1 | 1.13943768 | 4.73 |
| S | 6.97473693 | 9 | .77497077 | |
| AXS | 2.16672468 | 9 | .240747187 | |
| B | .54594624 | 1 | .54594624 | 1.04 |
| BXS | 4.7213093 | 9 | .524589923 | |
| AXB | 1.16587758 | 1 | 1.16587758 | 5.03 |
| AXBXS | 2.08203995 | 9 | .231337772 | |
| TOTAL | 18.7960725 | 39 | | |

CELL MEANS:

A1 B1 = 3.59072[illegible]3

A1 B2 = 3.48292954

A2 B1 = 2.91171905

A2 B2 = 3.4868235

DEPENDENT VARIABLE = BASELINE-SCALED % ALPHA
TRANSFORMED BY LOG(X+30)

Table 6. Summary of analysis of variance of reciprocal % alpha by feedback mode and feedback polarity.

ANOVA SUMMARY TABLE: MODE BY POLARITY

| SOURCE | S.S. | D.F. | M.S. | F |
|---|---|---|---|---|
| A | 1.24340737E-03 | 1 | 1.24340737E-03 | 2.15 |
| S | 1.99496974E-03 | 5 | 3.98993948E-04 | |
| AXS | 2.88833869E-03 | 5 | 5.77667738E-04 | |
| B | 8.08664699E-05 | 1 | 8.08664699E-05 | .93 |
| BXS | 4.33337789E-04 | 5 | 8.66665578E-05 | |
| AXB | 2.73883998E-05 | 1 | 2.73883998E-05 | .41 |
| AXBXS | 3.32092073E-04 | 5 | 6.64184147E-05 | |
| TOTAL | 7.00039553E-03 | 23 | | |

CELL MEANS:

A1 B1 = .0223002561

A1 B2 = .0281079846

A2 B1 = .0388324235

A2 B2 = .040367105

DEPENDENT VARIABLE = RAW % ALPHA
TRANSFORMED BY 1/(X+0)

Table 7. Summary of analysis of variance of arcsine cycle frequency by feedback mode and feedback polarity.

ANOVA SUMMARY TABLE: MODE BY POLARITY

| SOURCE | S.S. | D.F. | M.S. | F |
|---|---|---|---|---|
| A | .0863848105 | 1 | .0863848105 | .74 |
| S | .961924925 | 5 | .192384985 | |
| AXS | .579917073 | 5 | .115983415 | |
| B | .0231894925 | 1 | .0231894925 | 3.26 |
| BXS | .0355340988 | 5 | 7.10681975E-03 | |
| AXB | .0278338417 | 1 | .0278338417 | 7.74 |
| AXBXS | .0179584473 | 5 | 3.59168947E-03 | |
| TOTAL | 1.73274269 | 23 | | |

CELL MEANS:

A1 B1 = .977930006

A1 B2 = .847651548

A2 B1 = .789830559

A2 B2 = .795772054

DEPENDENT VARIABLE = RAW CYCLE FREQUENCY
TRANSFORMED BY ARCSINE(X+0)

Table 8. Summary of analysis of variance of square-root baseline-scaled % alpha by feedback mode and feedback polarity.

ANOVA SUMMARY TABLE: MODE BY POLARITY

| SOURCE | S.S. | D.F. | M.S. | F |
|---|---|---|---|---|
| A | 1.47294509 | 1 | 1.47294509 | .11 |
| S | 16.1641321 | 3 | 5.38804404 | |
| AXS | 39.1536011 | 3 | 13.0512003 | |
| B | 3.92918384 | 1 | 3.92918384 | 1.01 |
| BXS | 11.6306747 | 3 | 3.87689157 | |
| AXB | 1.30974019 | 1 | 1.30974019 | 3.3 |
| AXBXS | 1.18736744 | 3 | .395789146 | |
| TOTAL | 74.8476446 | 15 | | |

CELL MEANS:

A1 B1 = 5.95624375

A1 B2 = 4.39291587

A2 B1 = 4.77719956

A2 B2 = 4.35831059

DEPENDENT VARIABLE = BASELINE-SCALED % ALPHA
TRANSFORMED BY SQUARE ROOT(X+25)

Table 9. Summary of analysis of variance of arcsine baseline-scaled cycle frequency by feedback mode and feedback polarity.

ANOVA SUMMARY TABLE: MODE BY POLARITY

| SOURCE | S.S. | D.F. | M.S. | F |
|---|---|---|---|---|
| A | .0388611681 | 1 | .0388611681 | .38 |
| S | .0188447062 | 3 | 6.28156875E-03 | |
| AXS | .30188102 | 3 | .100627007 | |
| B | 1.96225126E-03 | 1 | 1.96225126E-03 | 1.43 |
| BXS | 4.09634924E-03 | 3 | 1.36544975E-03 | |
| AXB | .0118594922 | 1 | .0118594922 | 5.1 |
| AXBXS | 6.9634621E-03 | 3 | 2.32115404E-03 | |
| TOTAL | .38446845 | 15 | | |

CELL MEANS:

A1 B1 = .323492707

A1 B2 = .246893408

A2 B1 = .170475879

A2 B2 = .202777873

DEPENDENT VARIABLE = BASELINE-SCALED CYCLE FREQUENCY
TRANSFORMED BY ARCSINE(X+.29)

# APPENDIX D:

# CORRELATIONS AND REGRESSION

ALL SUBJECTS

X = FREQUENCY OF STATE CHANGE (FULL CYCLE IN HZ)

Y = PROPORTION OF TIME IN ALPHA

REGRESSION: Y = .549149122X -.0115604562

CORRELATION: R = .710708073

T = 20.3562678 DF = 406

N = 408

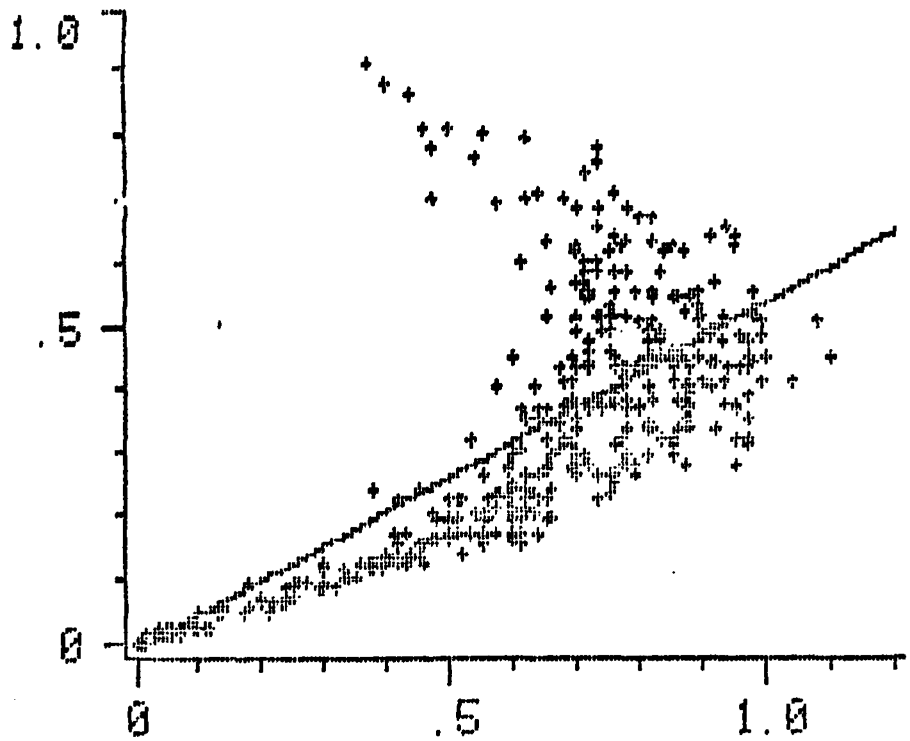


Figure 12. Correlation and regression: scatter plot of % alpha by cycle frequency across all trials and subjects.

ALL SUBJECTS, CONDITIONS 1, 3, 5, 7, 8

X = FREQUENCY OF STATE CHANGE (FULL CYCLE IN HZ)

Y = PROPORTION OF TIME IN ALPHA

REGRESSION: Y = .503360182X + .0583454899

CORRELATION: R = .596378496

T = 11.6292026 DF = 245

N = 247

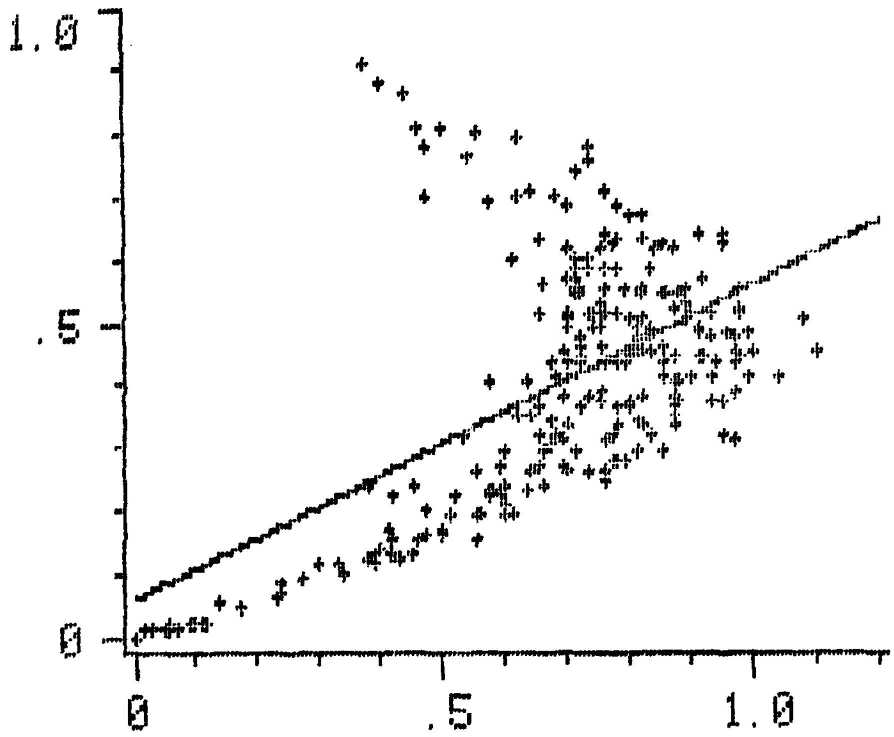


Figure 13. Correlation and regression: scatter plot of % alpha by cycle frequency across all subjects for eyes-closed trials.

ALL SUBJECTS, CONDITIONS 2, 4, 6, 9, 10

X = FREQUENCY OF STATE CHANGE (FULL CYCLE IN HZ)

Y = PROPORTION OF TIME IN ALPHA

REGRESSION: Y = .486940376X -.0386601179

CORRELATION: R = .877674487

T = 23.0920964 DF = 159

N = 161

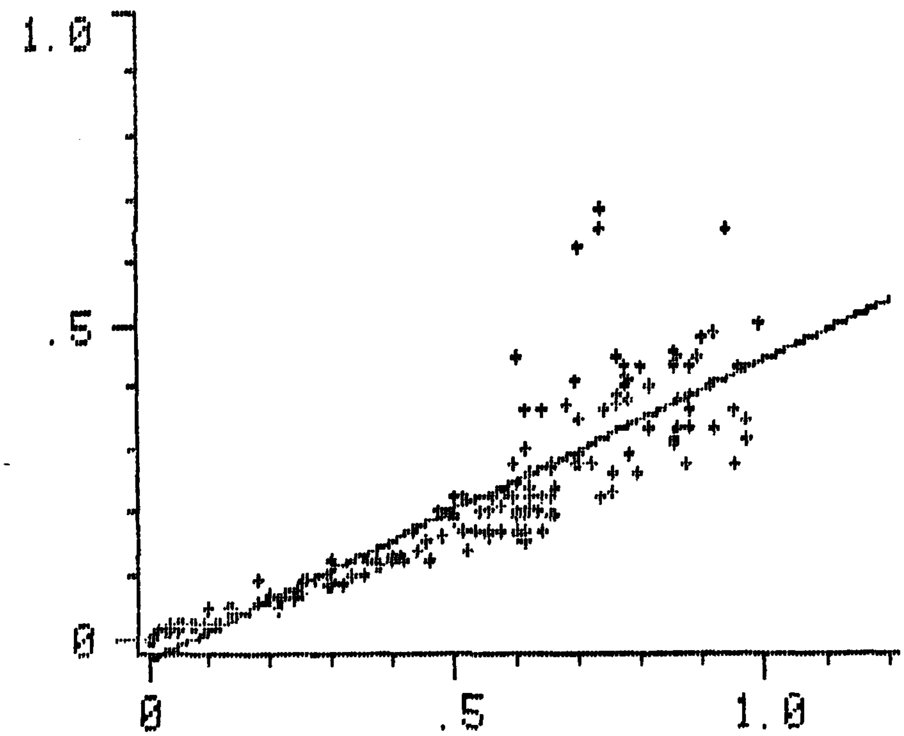


**Figure 14.** Correlation and regression: scatter plot of % alpha by cycle frequency across all subjects for eyes-open trials.

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